

**GERMINATING A NEW SEAD:  
THE IMPLICATIONS OF EXECUTING THE SEAD  
MISSION IN A UCAV**

BY

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## **Disclaimer**

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## ***About the Author***

Major David C. Hathaway was born in Waukesha, Wisconsin in 1965. In 1983 he graduated from Oconomowoc Senior High School and enrolled at the University of Wisconsin-Madison. In December of 1987, Major Hathaway graduated with a Bachelor degree in engineering mechanics. He was an ROTC Distinguished Graduate and received a regular commission upon graduation. In May of 1989, Major Hathaway was a Distinguished Graduate of European NATO Joint Jet Pilot Training. He then attended Lead In Fighter Training at Holloman AFB, New Mexico, followed by initial F-16 training at Luke AFB, Arizona. His first operational assignment was the 309<sup>th</sup> Fighter Squadron, Homestead AFB, Florida flying the F-16A and later the F-16CG. In August 1992 the squadron moved to Shaw AFB, South Carolina and was redesignated the 79<sup>th</sup> Fighter Squadron. At Shaw AFB, Major Hathaway flew the F-16CG and was later one of the first two operational instructors in the new F-16CJ. He also served a year as the aide de camp for the 9<sup>th</sup> AF/CENTAF Commander. His tour at Shaw AFB culminated with his selection to attend the F-16 Weapons Instructor Course at the USAF Weapons School, Nellis AFB, Nevada. In December 1995, Major Hathaway graduated from the Weapons School and was reassigned to the 35<sup>th</sup> Fighter Squadron, Kunsan AB, Republic of Korea where he served as both the Weapons Officer and a Flight Commander. In January 1997, Major Hathaway was handpicked to instruct at the USAF Weapons School. There he instructed in both the F-16CG and F-16CJ, and was the primary instructor for all air-to-air and APG-68 radar academics. At the Weapons School he served as the F-16 Division, Chief of Scheduling, the Air-to-Air Flight Commander, the Air-to-Air Weapons Employment Phase Manager, and the Weapons School Chief of Safety. In November 2000, Major Hathaway received a Master of Aeronautical Science from Embry-Riddle Aeronautical University. In addition to the schools listed above, Major Hathaway is also a graduate of the

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## *Abstract*

This study attempts to identify and explore the implications of executing the suppression of enemy air defenses (SEAD) mission in an unmanned combat aerial vehicle (UCAV) in 2015. To do this the thesis first explores the history of both the UCAV and the SEAD mission. Next, it discusses the three options being considered by the USAF to execute the 2015 SEAD mission: a space-based option, modernized manned aircraft with advanced weapons, and a UCAV. The author then analyzes the three options in their ability to effectively execute the SEAD mission based on fiscal cost, risk to human life, feasibility, and mission effectiveness. He then discusses other issues the USAF should consider before implementing the UCAV option. The study concludes by recommending the UCAV as the most effective SEAD option for 2015, with a few caveats.

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## Chapter 1

### INTRODUCTION

On July 24, 1965 the North Vietnamese launched the first of thousands of SA-2 surface-to-air missiles (SAM) against U.S. strike aircraft. Before the SA-2 was fielded, pilots avoided much of the enemy ground fire by flying above it. The SA-2 being most effective at altitudes near 20,000 feet negated this tactic.<sup>1</sup> This was a dramatic step in the continuous move/counter-move development in technology and tactics apparent as far back as World War II. The response to this technological advance of the SAM was the dedicated aircraft to identify, target, and engage these threats. Thus the mission of suppression of enemy air defenses (SEAD) was born. Since Vietnam the U.S. has seen a continuous battle between primarily Russian air defense technology and tactics, and US SEAD assets. As we look to the future, the U.S. faces an increasingly difficult problem. The Russians, as well as others, are developing increasingly lethal air defenses. To date, the U.S. has been able to keep pace with this increasing threat. However, as Russia continues deployment and export of the SA-10 and SA-12, and prepares to field an even more advanced SAM, the SA-20, current US equipment and tactics will no longer be able to protect forces airborne. The challenge for the U.S. is to develop the next generation of SEAD platforms to survive in this environment whether they are manned or unmanned aircraft, or possibly even space-based systems. To answer this challenge the Air Force is leaning toward an unmanned combat aerial vehicle (UCAV). The question is, is the UCAV the best option to execute the SEAD mission in 2015?

#### Problem Background and Significance

Beginning as early as World War II there has been a continuous attempt on the enemy's part to counter every advance in US airpower technology or tactics with a corresponding advance

combat aerial vehicle (UCAV) to answer this challenge. This study examines the implications of executing the SEAD mission from a UCAV as compared to other possible SEAD solutions.

### Limitations, Assumptions, and Criteria

This section presents the limitations and assumptions affecting the conclusions arrived at in this thesis. It also discusses the criteria used in selecting possible solutions to the challenges to the SEAD mission.

#### Limitations

The first limitation is that the subject deals with a problem to be decided on around 2005-2007 and implemented around 2015. At the time of this research, many of the technological and fiscal questions have not been fully answered. Many of the implications of the various possible ways to execute the SEAD mission have not even yet been identified. For this reason there is a certain amount of speculation on the part of the various sources and the author. To present the most accurate picture of the possible options for the next generation of SEAD platform, the author made all attempts to contact personnel working closest to the problem. However, since many of the concepts have yet to be proven, some speculation on capabilities of the proposed systems does exist.

The second limitation has to do with the classification of many programs. This paper is limited to unclassified material, so as to facilitate dissemination to the widest possible audience. Wherever possible classified programs are discussed in general enough terms to be presented at the unclassified level. However, limiting to the unclassified level often may lead to an incomplete picture of the importance of some implications with respect to the selection of a particular solution to the SEAD problem.

#### Assumptions

As a common frame of reference for comparing the UCAV to other possible SEAD solutions, the author assumes an advanced, Russian-built integrated air defense system (IADS). The author is not implying that the U.S. will always fight a Russian-built IADS. However, a Russian-built air defense system is one of the most advanced in the world. If the selected SEAD platform can meet the challenge presented by these threats, it should be able to handle a less sophisticated or capable threat.

## Criteria

When comparing the UCAV to other possible solutions for the challenges to the future SEAD mission, this paper compares solutions on the basis that they will have to be reactive and responsive to mobile threats. This is not to say that a cruise missile attacking a known prepared SAM site is not a possible SEAD weapon. However, a cruise missile is not likely to be effective against mobile or previously unknown SAM locations. It also won't be responsive enough to provide protection to aircraft that come under fire from air defenses. The tougher problem to solve is how does the U.S. put a SEAD platform close enough to the threat to be responsive, while yet being survivable?

This thesis evaluates the UCAV and other SEAD options based on several criteria. They are as follows:

- Least costly fiscally
- Lowest risk to human life
- Feasibility
- Effectiveness in SEAD mission

## Definitions

This section lays the groundwork for the remainder of the thesis. It explains the meaning of the terms commonly used for which an understanding by the reader is critical. Many of the terms used when discussing unmanned vehicles, for example, have subtly different meanings, but are often used interchangeably. However, the reader must understand those differences in order to understand the weight in the argument.

The first group of related terms has to do with unmanned aerial vehicles (UAV). A UAV simply implies that there is no pilot in the craft. It does not imply that there is no person in the decision loop. A UAV like the USAF Predator is unmanned, but is flown from a ground station. This type of UAV is called a remotely piloted vehicle, or RPV. An RPV may also be described as an *uninhabited* aerial vehicle, implying that there is a pilot, or operator. They just aren't physically in the aircraft. An RPV has a pilot actually manipulating controls that are data-linked to the UAV from some external location that can be land, sea, or air-based. The key is that the RPV is directly responding to pilot inputs. UAVs used as targets or decoys may also be called drones and are typically remotely piloted. Another type of UAV is more like the cruise missiles of today. They can be preprogrammed with their mission specifics and do everything from

takeoff through landing. These are described as autonomous UAVs. The USAF Global Hawk is in this category.<sup>3</sup> This does not necessarily imply that there is not a pilot/operator in the loop. Pilots/Operators may still have the ability to monitor the mission remotely and may even have the ability to override the UAV's actions when necessary. However, the autonomous UAV will not require pilot input to takeoff, navigate, carry out mission specifics, or land. The unmanned combat aerial vehicle (UCAV) is a specific type of UAV. It employs ordnance. This ordnance could range from bombs to missiles, or possibly laser weapons. Additionally, just like the UAV, the UCAV can be either remotely piloted or autonomous.

A second concept that must be understood is the suppression of enemy air defenses (SEAD) mission. The means to accomplish the SEAD mission may be either lethal or non-lethal. A lethal means may be a high-speed anti-radiation missile (HARM), while a non-lethal means may be electronic jamming of the system's radar. There is also a subset of lethal SEAD called destruction of enemy air defenses, or DEAD. The difference between DEAD and some other forms of lethal SEAD is the level of destruction. For example a HARM missile may only cause enough damage to temporarily disable the threat it was employed against, whereas a 2000 lb laser-guided bomb (LGB) is much more likely to destroy the site permanently.

### Preview of Argument

Chapter two of this thesis presents the historical background of the UCAV. It begins with the initial employment of UCAVs in World War I and finishes with the February 2001 Hellfire shot from a Predator UAV.

Chapter three provides the historical perspective on the SEAD mission. It covers the period of US involvement during Vietnam through Operation Allied Force, which brings the SEAD mission from infancy through its current capability.

Chapter four describes the future air defense threat and the implications to US SEAD platforms being employed today. It describes the capabilities of the advanced Russian-built SAMs currently being exported around the world and those that will soon be made available.

Chapter five presents the three most generally accepted SEAD options, space-based weapons, modernized manned aircraft armed with advanced weapons, and a UCAV. It describes some of the implications associated with choosing a particular option.

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<sup>3</sup> Hugh McDaid and David Oliver, *Smart Weapons: Top Secret History of Remote Controlled*

The remaining chapters analyze the criteria used in evaluating a particular SEAD solution and then discuss the implications of pursuing the UCAV option. To this end, it looks at the effectiveness of the various options to perform the SEAD mission, by comparing the cost in lives, cost in dollars, and feasibility of implementation. However, no option is perfect. There are fiscal considerations as well as technological hurdles that must be cleared before the UCAV will take its place as the new Wild Weasel.<sup>4</sup>

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*Airborne Weapons* (New York: Welcome Rain, 1997), 119.

<sup>4</sup> The Wild Weasel is a term that originated during the Vietnam War to identify USAF aircraft specially modified to with radar warning receivers. This capability first employed on the F-100F allowed the electronic warfare officer (EWO) the first ability to identify a specific radar type, and attempt to locate its position. The term now implies aircraft specially equipped to execute the SEAD mission.

## Chapter 2

### HISTORICAL PERSPECTIVE: THE UCAV

*We have just won a war with a lot of heroes flying around in planes. The next war may be fought by airplanes with no men in them at all. It certainly will be fought with planes so far superior to those we have now that there will be no basis for comparison. Take everything you've learned about aviation in war, throw it out the window, and let's go to work on tomorrow's aviation. It will be different from anything the world has ever seen. .*

*General Hap Arnold, 1945*

#### Introduction

The use of an unmanned vehicle is generally considered advantageous when the following three criteria are met:<sup>5</sup>

1. When the lethality of the mission is too great or when our cultural norms prohibit us from committing soldiers to suicide missions. Robotic vehicles may survive extremely toxic or explosive environments and, if destroyed, only an expensive piece of equipment needs to be replaced.
2. When human resources need to be diverted to other priorities. Robotic systems can free essential manpower to perform higher priority missions by taking on less complex, redundant missions.
3. When the overall efficiency and effectiveness of a task can be better accomplished through automation.

Throughout the history of aircraft in war, militaries have attempted to use unmanned aircraft in response to increased risk, whether actual or perceived, to manned aircraft. They also used unmanned aircraft when it was too politically sensitive to send manned aircraft, as in the case of photoreconnaissance flights over another country's

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<sup>5</sup> Steven M. Shaker and Alan R. Wise, *War Without Men* (New York: Pergamon-Brassey's, 1988), 161.

sovereign territory. However, the problems have historically developed in the third criteria above. Technology typically had limited the efficiency and effectiveness of unmanned vehicles, in particular the unmanned combat aerial vehicle (UCAV). In fact, due to technological limitations there wasn't any distinction between UCAVs and cruise missiles. It wasn't until the Vietnam War that the command and control technology had progressed far enough to develop a true UCAV, one that could fly to a target, expend ordnance, and then return for reuse. Therefore, many of the early UCAV designs don't fit into the modern definition, as they had limited human control once launched and didn't return for reuse.

The UCAV in the simplest terms is a traditional ordnance-employing airplane without the pilot in a cockpit. However, there are actually two categories of UCAV that describe how it is controlled: the remotely piloted vehicle (RPV) and the more autonomous, preprogrammed UCAV that may or may not have an operator as a monitor of mission performance. This chapter briefly reviews the history of UCAVs from initial conception to the present. The history of UCAVs is a subject large enough in scope to justify a book on its own. In fact there are already several books on unmanned aircraft. The intent here is not repeat previous work. Instead, this chapter is limited to the development of unmanned vehicles for the express purpose of getting ordnance on target. It does not discuss cruise missiles, although many of the early-unmanned vehicles described are predecessors of the cruise missile. It does, however, touch upon the use of UAVs in reconnaissance to illustrate the split between the UAV and the cruise missile. Lastly, as SEAD is currently the mission the UCAV is proposed to adopt, it briefly discusses the role of RPVs in support of the SEAD mission,

### **The Initial Years: World War I through World War II**

During World War I, while manned aircraft were still in their infancy researchers began to see the advantages of having unmanned aircraft as well. Heavy British pilot losses, as well as the inability to intercept the German built Zeppelin airships instigated a research program at the Ordnance College of Woolrich. The researchers wanted to develop an RPV designed to glide to its target, and explode on impact. Using this research, the Royal Aircraft Factory initiated multiple RPV designs though several

aircraft manufacturers. The basic design was a small-scale biplane built around an expendable 35-hp engine. It contained the required receiver and control equipment needed to remotely pilot the vehicle, and could carry a 50 lb warhead in its nose. Unfortunately, the RPV technology proved to be too elusive at this time. After several mishaps, including one demonstration in which the RPV went astray and dove at the crowd, the British program failed to produce a viable RPV by the end of the war.<sup>6</sup>

In the U.S. both the Navy and the Army were developing their own versions of the flying bomb. The Navy's program was based on a gyro-stabilization unit developed by Dr. Elmer Sperry. This gyro-stabilization unit was the heart of an autopilot initially designed to augment the pilot. The Navy asked Dr Sperry to adapt this technology to create an aerial torpedo. The resulting aircraft was the Curtis flying bomb. Unlike the British designs, this was not an RPV. The gyroscope would be set to fly a certain direction and a certain altitude. Once the desired distance was attained, the engine would be cut off and a mechanical device would remove the wings. The fuselage and explosive would then fall on the target. The Curtis flying bomb was the first "robot" aircraft.<sup>7</sup>

The US Army initiative resulted in the Kettering Bug unmanned aircraft (fig.1). It was similar in design to the British initiatives, however the Kettering Bug performance surpassed their unmanned aircraft capabilities. The Kettering Bug could carry a bomb weighing 180 lbs at 55 mph for a distance of 40 miles. It would be flown to the target at which time the controls would be stopped. It would then nose dive into the intended target. However, the war ended soon after the first successful test. Therefore like the British, the U.S. did not field an operational UCAV during World War I.<sup>8</sup>

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<sup>6</sup> Steven M. Shaker and Alan R. Wise, *War Without Men* (New York: Pergamon-Brassey's, 1988), 21.

<sup>7</sup> *Ibid.*, 22.



**Figure 1. Kettering bugs ready for takeoff in 1918 (Courtesy of the Air Force Museum Archives, Dayton).**

Although the test phase of the Kettering Bug was plagued with mishaps, the few successes maintained interest in the concept of the flying bomb. Throughout the 1920's work on improvements to RPVs continued. The Sperry Corporation and the U.S. Army Air Corps continued development of radio control mechanisms until the Great Depression of the 1930s forced the program cancelled for budgetary reasons.<sup>8</sup>

Throughout the 1920s the British also continued development of unmanned vehicles. They viewed them as a cost-effective alternative for some manned-flight missions. They explored several options, some continuing along the lines of other flying bombs, and others that could fly to a target then expend a bomb. The British were successful in developing a monoplane design that used gyroscopic technology similar to

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<sup>8</sup> Ibid.

<sup>9</sup> Ibid., 24.

the US designs, and a clockwork control device that would actuate the controls in a preprogrammed sequence. This design married with a 200-hp Lynx engine could carry a 200 lb bomb at speeds up to 193 mph, which was faster than any manned aircraft of the time. Twelve of these aircraft dubbed the LARYNX were built by the British and successfully launched from both ground installations and warships. They also did a test of limited success in the Iraqi desert. However, the British initiatives were not limited to the development of unmanned aircraft for combat.<sup>10</sup>

Unmanned aircraft technology was also being developed for use as airborne targets. This was instigated by the debate over the vulnerability of capital ships to attack from the air. Billy Mitchell's test sinking of several warships by U.S. Army Air Service aircraft fueled this debate. As a result the British Navy increasingly needed airborne targets for their gunnery practice. Consequently, by the 1930s the interest in the pre-programmable LARYNX faded, as the emphasis shifted more towards the development of these radio-controlled aerial targets.<sup>11</sup>

## World War II

Throughout the mid-1930s development of RPVs continued. The U.S. developed an RPV called the RP-4, while the British developed the much faster Queen Bee. As World War II broke out, follow-on derivatives of these RPVs that were faster and higher flying were ordered in mass numbers. However, these RPVs were strictly for target practice. None was intended for combat.<sup>12</sup>

At the onset of World War II, however, General Motors designed a flying bomb capable of carrying 500 lbs of explosive for 50 miles. Fifteen of the GM Bomb Bugs, as they were known, were built. During testing 12 of them were destroyed, so the U.S. Army Air Force determined that there were other more effective and promising programs available and the GM Bomb Bug was abandoned. Later in 1942 and 1943, the USAAF again tried its hand at two different remote-controlled flying bombs that were designed to

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<sup>10</sup> Sir Michael Armitage, *Unmanned Aircraft* (London: Brassey's Defence Publishers, 1988), 4.

<sup>11</sup> Steven M. Shaker and Alan R. Wise, *War Without Men* (New York: Pergamon-Brassey's, 1988), 25.

<sup>12</sup> *Ibid.*, 26.

crash into their targets. However, they too were abandoned as the USAAF opted instead on converted manned-aircraft.<sup>13</sup>

Other initiatives involved converting manned bombers to RPVs. In the Pacific theater, the U.S. employed a few remotely piloted single-engine monoplanes loaded with heavy bomb loads. However, due to high aircrew losses in the European theater, a more extensive program to introduce unmanned bombers was undertaken. Beginning in 1944, damaged or time-expired B24s and B-17s were converted to remote control bomb-laden aircraft. A pilot and a technician would fly these aircraft from takeoff until approaching the English Channel. At this point the pilot and technician would bail out and the aircraft would be remotely piloted over the continent and crashed into their Nazi targets. Eventually this program was cancelled due to its cost and the technical problems associated with converting these large multi-engined bombers to remote control.<sup>14</sup> These unmanned aircraft initiatives were not limited to the Allied powers.



**Figure 2. A V-1 in its final dive over England during WWII (Courtesy of Air Force Museum Archives, Dayton).**

During World War II, the Germans developed very effective flying bombs. A

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<sup>13</sup> Sir Michael Armitage, *Unmanned Aircraft* (London: Brassey's Defence Publishers, 1988), 30.

<sup>14</sup> *Ibid.*, 32.

prototype of the V-1 Buzz Bomb existed in the 1930s and went into production in 1941. It was a less costly and complex system than its cousin the V-2 rocket. Like many of the initial U.S. Navy designs, the V-1 was not remotely piloted. It had a gyroscope used to maintain direction and an altitude between 1000 and 7000 feet at slightly over 400 mph. It could maintain this speed for a range of up to 250 miles. A small propeller in the nose acted as a crude distance-measuring device that would shut off the fuel at the preprogrammed distance. The V-1 would then initiate a dive into its target.<sup>15</sup> The V-1 was not very efficient if you look strictly at the numbers of targets struck versus the number of V-1s launched.

Ten-thousand, five-hundred sorties were launched against England from June 12, 1944, through March 30, 1945. Only 2,500 survived both mechanical failures and the enemy's defenses to penetrate to their target. The V-1 was quite often shot down by air or ground fire. They were occasionally tipped over by the wing of a fighter, causing them to veer out of control and then plunge into the English Channel. Nonetheless, they caused 14,655 casualties.<sup>16</sup>

Even though the success rate of V-1 sorties was less than 25 percent, the relative cost of creating that number of casualties was low as compared to attempting to do the same mission with manned bombers.<sup>17</sup>

### **Post World War II through Vietnam**

In the early 1950s the United States acquired its first jet-powered unmanned aircraft. However, like many of its US predecessors, the Firebee was not designed for combat, it was designed as a target drone for manned aircraft. The unmanned aircraft used for combat continued to be converted manned aircraft, such as the Navy's use of surplus F6F Hellcats during the Korean War. The Hellcats were converted to remote

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<sup>15</sup> Steven M. Shaker and Alan R. Wise, *War Without Men* (New York: Pergamon-Brassey's, 1988), 27.

<sup>16</sup> *Ibid.*, 28.

<sup>17</sup> This argument does not address the high opportunity cost of developing and employing the V-1. Although compared to manned bombers, the V-1 was a more cost effective way to create civilian casualties, and thus attempt to attack the will of the British populace, the Germans were losing air superiority over their homeland. The resources diverted to produce the V-1 may have been better used in regaining and maintaining their homeland defense.

control, laden with bombs, and guided into heavily defended Communist targets.<sup>18</sup>

The Hellcats used in Korea, like almost every other explosive-laden unmanned vehicle up to this point, were designed to go on one-way missions. They were not designed to be recovered or reused. It is at this point that there is a departure from the existing paradigm to the two categories now thought of as cruise missiles and UAVs. Cruise missiles continued their development from the initiatives made with the flying bomb, while the UAVs derived from the work done with drones created as airborne targets.

The shoot down of two manned U-2 aircraft over the Soviet Union and Cuba in the early 1960s further emphasized the need to relieve manned aircraft from highly dangerous or politically sensitive missions. The USAF subsequently focused its unmanned effort towards photoreconnaissance. This continued into the Vietnam War with the desire to limit the aircrew losses due to surface-to-air missiles. Again RPVs were put to the task.<sup>19</sup>

During the Vietnam War, the introduction of the SA-2 significantly increased the risk to manned aircraft. To reduce that risk the U.S. again considered unmanned aircraft. The USAF employed RPVs to do some of its low altitude photoreconnaissance, as well as electronic eavesdropping, jamming, and dispensing chaff corridors, while the manned aircraft focused on suppressing the new SAM threat.<sup>20</sup>

### **The Israeli Experience**

The Israelis facing Egypt in 1973 had a similar problem to that of the U.S. in Vietnam. SAMs increased the risk to aircraft. However, the Israelis didn't just face the SA-2 threat. They also encountered the much more lethal SA-6, as well as the shoulder fired SA-7 and the ZSU-23-4 AAA. Additionally, these threats were much denser than those Vietnam.

As the Egyptians built up forces, the Israelis devised plan that used RPVs to draw fire and subsequently reduce the AAA and SAM threat to follow-on manned aircraft strikes. However, when war came in 1973, the Israelis initially opted for a manned

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<sup>18</sup> Ibid., 30.

<sup>19</sup> Ibid., 31.

strike, which resulted in the loss of over 30 aircraft on the first day. They then resorted back to their initial plan and sent their RPVs in ahead of their next manned strike. After the Egyptians fired their initial salvo at the drones, the manned strikes were then able to attack while the Egyptians were reloading. This attack allowed the Israelis to gain control of the skies.<sup>21</sup>

In addition to using the RPVs as decoys, the Israelis also experimented with using their drones as UCAVs. In 1971 the U.S. began testing of a BGM-34B Firebee in the test range adjacent to Hill AFB, UT. They demonstrated the capability to employ an assortment of ordnance from the drone, including Stubby Hobo and Maverick missiles and MK-81/82 series dumb bombs (fig. 3).<sup>22</sup> Due to the pullout of US forces from Southeast Asia, the U.S. did not employ this new weapon in Vietnam. However the Israelis took advantage of the technology to reduce risk to manned aircraft. They loaded their BGM-34-A RPVs with AGM-65 Maverick missiles. The target was designated off-board by a relayed TV picture from a camera in the nose of the drone. This image was then relayed to the camera in the AGM-65, which then automatically guided to the target. They were used to target both air defense sites and armored vehicles (fig. 4).<sup>23</sup> This was the first time the modern concept of a UCAV was employed in combat, an unmanned aerial vehicle taking off, expending ordnance, and returning for reuse.

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<sup>20</sup> Ibid.

<sup>21</sup> Ibid., 32-34.

<sup>22</sup> William Wagner and William Sloan, *Fireflies and Other UAVs* (Arlington, Texas: Aerofax Inc., 1992), 100.

<sup>23</sup> Steven M. Shaker and Alan R. Wise, *War Without Men* (New York: Pergamon-Brassey's, 1988), 34



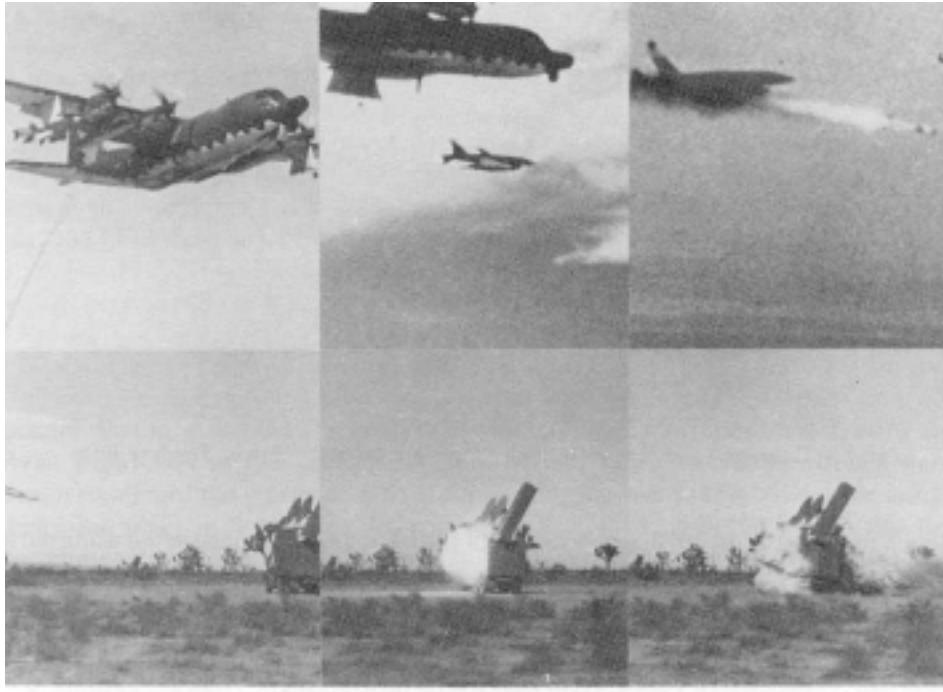
**Figure 3. The BGM-34B with its possible weapons including rockets, bombs, and air-to-surface missiles (Courtesy of Barnes and Noble Publishing).**

In 1982, the Israelis invaded Lebanon to destroy Palestinian guerrilla strongholds in the Bekaa Valley. However, this resulted in an intense conflict with the Syrians. The Israelis realized that the only way they could establish air superiority over Lebanon airspace was to rid the area of the Syrian-manned SA-6 missiles. Once again, the Israelis depended on their RPVs to stimulate the SAM threat, but in this case they were also an integral part of the SEAD plan.<sup>24</sup> As it was part of a SEAD plan the next chapter discusses it more in depth. However, the outcome was an overwhelming success that had great influence on the US led SEAD campaign during the 1991 Gulf War.<sup>25</sup>

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<sup>24</sup> Ibid., 36.

<sup>25</sup> Dr. Elliot Cohen, et al, *Gulf War Air Power Survey*, 5 vols. (Washington D.C.: U.S. Government Printing Office, 1993), 2:116.



**Figure 4. The sequence of events from BGM-34 release from its mother ship to Maverick missile impact on a surveillance radar van on 14 December 1971 (Courtesy of the Ryan Aeronautical Library).**

### **Post Vietnam**

After Vietnam the U.S. once again shifted away from the UCAV concept in favor of manned aircraft. Many of the reconnaissance RPVs used during Vietnam were shipped back to the U.S. and stored in warehouses mostly at Warner-Robins AFB, GA and Hill AFB, UT. It wasn't until 1987 that these veterans of the Vietnam conflict were restored and returned to duty as target drones for various tests.<sup>26</sup> In the meantime the US Navy did some follow-on experimenting with RPVs, but like the Air Force the Navy emphasized reconnaissance platforms and target drones.

It wasn't until the planning for the Gulf War in 1990 that military planners again recognized the combat need for a drone. In developing their SEAD campaign, the military planners drew from the 1982 Israeli experience in the Bekaa Valley. Unfortunately, the Air Force found that due to years of neglect it had no viable drone to

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<sup>26</sup> William Wagner and William Sloan, *Fireflies and Other UAVs* (Arlington, Texas: Aerofax Inc., 1992), 142.

support the SEAD plan. Air Force planners had to turn to the Navy and their BQM-74s and Tactical Air Launched Decoys (TALD).<sup>27</sup> As with the Israeli's Bekaa Valley experience, this is discussed in depth in the next chapter.

## Today

The US military does not have an operational UCAV in its inventory today. However, it does have two UAVs that incorporate some of the technologies necessary to develop a viable UCAV in the future. These are the Predator and Global Hawk UAVs.

### Predator

The RQ-1A Predator UAV is the primary UAV in the USAF today. It has two roles, reconnaissance and target acquisition. It flies at a slow loiter speed of 60 knots, and has a service ceiling of 25,000 feet. It is remotely piloted from a ground station, although it can be flown with a preprogrammed autopilot as well. Predator has an extensive sensor suite including a camera, electro-optical and infrared sensors, electronic and communications intelligence sensors, laser range finder/designator, and communications relay. Predator's data link includes a radio command uplink operating in the C-band when it is within line of sight (LOS) of the ground station, or KU-band and UHF when it is beyond LOS. Additionally, it has a data down link for real-time imagery.<sup>28</sup> Predator has played a crucial reconnaissance role in both the Bosnia and Kosovo conflicts.

After 30 years the USAF once again demonstrated the ability of an unmanned aerial vehicle to employ ordnance. In February 2001 the Air Force used the Predator as a launch platform for a test firing of a Hellfire missile against a tank. In the live-fire test the Predator was remotely piloted via the Ku-band satellite link beyond LOS of the ground controllers. The Predator's infrared sensor and laser designator were used to locate, track and illuminate the target for the Hellfire missile. From an altitude of 2000 feet the Predator lased its target and launched the Hellfire, which completely immobilized

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<sup>27</sup> Michael Gordon and General Bernard Trainor, *The General's War* (New York: Little, Brown and Company, 1995), 113.

the tank by blowing off its track. In subsequent tests the Air Force hopes to demonstrate the capability to employ Hellfires from higher altitudes, 10,000 and 15,000 feet. It also hopes the test will provide information regarding UAV flying qualities and vibration while employing ordnance that will be valuable to future UCAV developments.<sup>29</sup>

## **Global Hawk**

The newest UAV in the USAF is the Global Hawk. It is an advanced reconnaissance UAV designed for missions requiring long-range deployment (14,000 miles plus) and/or protracted loiter above or near a target area. Like Predator, Global Hawk is not stealthy, thus it is not intended for use in a high-threat environment. However, with its state of the art electro-optical (EO), infrared (IR) and synthetic aperture radar (SAR) sensors, it can stand off a considerable distance and still accomplish its mission. In addition to stand off, it can operate as high as 65,000 feet and is equipped with electronic jammers and decoys for self-protection. With all these things, the Global Hawk is difficult but not impossible to shoot down. Its sensor suite provides detailed video and still pictures to the worldwide US military network through its high-speed satellite uplink. However, the technology that will lend itself toward the development of future UCAVs is its ability to operate autonomously. The operators do not fly the Global Hawk. In fact the operator doesn't even have any type of joystick to make flight control inputs. The Global Hawk flies by autopilot alone. The operator only inputs where they want it to go and what they want to look at. Global Hawk does the rest. To accomplish this task takes significant computer power. In fact, the computer power of Global Hawk is greater than any other UAV to date.<sup>30</sup>

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<sup>28</sup> Hugh McDaid and David Oliver, *Smart Weapons: Top Secret History of Remote Controlled Airborne Weapons* (New York: Welcome Rain, 1997), 107.

<sup>29</sup> Linda de France, "Predator Fires Live Missile in First Test of Weaponized UAV," *Aerospace Daily*, 23 February 2001, n.p.; online, Internet, 28 February 2001, available from <http://ebird.dtic.mil/Feb2001/e20010223predator.htm>.

<sup>30</sup> Hugh McDaid and David Oliver, *Smart Weapons: Top Secret History of Remote Controlled Airborne Weapons* (New York: Welcome Rain, 1997), 119.

## **Conclusion**

Unmanned aircraft have been designed, developed, and used since the introduction of the aircraft into combat in World War I. Military planners saw the desirability of unmanned aircraft based on the high risk of manned aircraft losses in certain situations and missions. However, technological limitations and budgetary constraints prevented the UCAV from making a significant impact in the past. Military planners now face the same problems as the U.S. in Vietnam and the Israelis in 1973 and 1982. The advances in surface-to-air missiles have once again begun to threaten the ability of US airpower to control the skies over a potential adversary. The USAF, with the help of new advances in technology, is now looking again at the possibility of unmanned aircraft employed to reduce this threat. This key role is the suppression of enemy air defense mission.

## Chapter 3

### SEAD FROM BIRTH TO MATURITY

#### Introduction

Since the advent of the airplane in combat, ground forces have looked for ways to defend themselves against air power. This has appeared in the form of aircraft-to-aircraft engagements, small arms fire, anti-aircraft artillery, and eventually surface-to-air missiles. During World War I although attempts were made to hit aircraft with small arms and artillery, the threat imposed by aircraft created the symmetric response of engaging aircraft with other aircraft. This resulted in the first air-to-air dogfights. During the interwar period as bomber aircraft were being developed, so were advances in air defenses, both in air defense aircraft and in ground-based air defenses. As a result as the Allies entered World War II, they found themselves facing German defenses of AAA and air defense fighters of a density never seen before. The US solution to the German air defense fighters was first thought to be tight bomber formations armed heavily with machine guns for their own self protection. When this proved to be ineffective against German fighters, the U.S. eventually incorporated the use of escort fighters with drop tanks to give them the necessary range. However, the dense AAA presented another problem. A report from Headquarters Eighth Air Force describes German flak as the greatest cause of damage and loss to US aircraft. The Allies made several attempts to neutralize the German AAA through direct attack by both fighters and bombers, since the AAA proved to be a significant threat to both.<sup>31</sup> However, the primary Allied solution to

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<sup>31</sup> William A. Hewitt, *Planting the Seeds of SEAD: The Wild Weasel in Vietnam* (Maxwell AFB, Ala.: Air University Press, June 1983), 4.

this problem was avoidance. Medium altitude bomber employment helped decrease the effectiveness of German AAA. However, it also decreased the accuracy of the US heavy bombers. Towards the end of World War II the Germans attempted to develop a much more effective ground-based defense, the surface-to-air missile (SAM). They saw the potential of such a weapon, however the technology necessary to provide guidance for a SAM was not mature enough.<sup>32</sup> Therefore, AAA continued to be the primary ground-based defense. This theme of avoiding ground-based AAA, while engaging enemy fighter aircraft, continued throughout the Korean conflict and into the Vietnam War. However, in 1965 the rules of the game changed forever with the operational employment of radar-guided SAMs by the North Vietnamese against US aircraft. The employment of the SAM created the necessity for a new mission, the suppression of enemy air defenses (SEAD), which drove the development of aircraft systems and weapons specifically designed for that purpose.

This chapter presents an overview of the development and maturation of the suppression of enemy air defenses mission. It includes both the U.S. experience beginning in Vietnam through Operation Allied Force and the Israeli experiences in the 1970s and 1980s with their US-built aircraft versus the Soviet-built ground defenses.

## **The Vietnam War**

The dawn of the SEAD mission was driven by the introduction of the soviet-built SA-2 SAM in July 1965 during the Vietnam War. Several things impacted the relative effectiveness of the SAM during this conflict. First, the SAM is a guided weapon. Although radar-aimed AAA was being employed, the AAA rounds were unguided once they left the barrel. The SAM being guided to impact increased the threat significantly. Secondly, although the U.S. recognized this threat, they did not prevent the North Vietnamese from building up their supply of SAMs. This was due to the employment of many of the SAM sites within the prohibited zones around Hanoi and Haiphong established by the Johnson administration. This prevented the U.S. from directly attacking many of the SAMs while also allowing the unhindered import of SAMs and their associated equipment through the Haiphong harbor. It wasn't until April 1972 that

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<sup>32</sup> Michael J. Neufeld, *The Rocket and the Reich* (New York: Free Press, 1995), 152.

the US administration lifted restrictions around Haiphong and the harbor was mined.<sup>33</sup> Additionally, the North Vietnamese began to increase its AAA strength to the point where, in selected areas, the density surpassed the concentrations of AAA during World War II and Korea.<sup>34</sup> These increased air defenses instigated a counter response from the U.S.

The SEAD mission developed rapidly in response to the new and serious threat posed by the Soviet-built SA-2. It began with the initial modification of current aircraft with electronic warfare equipment and the development of SAM suppression tactics.<sup>35</sup> Later the U.S. developed specialized weapons designed specifically to counter the SAM. During Vietnam these initiatives resulted in the development of three tactics to reduce the SAM threat.

The first tactic used to directly attack North Vietnamese SA-2s was to employ several F-105s ahead of the ingressing strike force to attack SAM sites before the strike force was vulnerable. This tactic failed, because the North Vietnamese quickly learned to turn their S-band fire control radars off until the strike aircraft came within range. This did not give the F-105s enough time to locate and attack the SAMs before the strikers had to threat react. Additionally, the ability of the North Vietnamese to position SAMs and their associated fire control radars just inside the prohibited zones around Hanoi and Haiphong, provided many SAMs a sanctuary. The North Vietnamese surrounded those SAMs outside the prohibited zones with increasingly dense shields of light and medium-caliber AAA to counter US attempts to attack the SAM sites. Complicating the problem further, the SA-2 and its fire control radar were relocatable. Consequently, US attacks against the SAM batteries often resulted in expending ordnance on empty sites.<sup>36</sup> While the USAF was attempting to attack the SAM sites with F-105s, it also tried to negate their effectiveness through other means.

The second tactic to counter the North Vietnamese air defenses was jamming. In late 1965, US electronic warfare aircraft, the EB-66, began acting in coordination with

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<sup>33</sup> Benjamin F. Cooling, *Case Studies in the Achievement of Air Superiority*, (Washington DC: Air Force History and Museums Program, 1991), 510.

<sup>34</sup> Ibid., 511.

<sup>35</sup> Ibid.

<sup>36</sup> Ibid., 531.

strike packages to jam North Vietnamese radars, thus masking the ingressing strike packages.<sup>37</sup> The EB-66 was fairly effective against early warning (EW) radars. Therefore, EW radars could not effectively identify and hand off strike package locations to the SAM fire control radars. Additionally, the EB-66 was effective against the AAA radars, like the Fire Can. However, the EB-66 was not as effective against the SAM fire control radars themselves, especially at the ranges at which the EB-66 was forced to standoff. Consequently, although the EW detection was degraded, the SAM fire control radars could still autonomously detect and target the strikers.<sup>38</sup> However, because the fire control radars had to be up and operating to autonomously target the inbound strikers, they were more vulnerable to the third tactic employed.

The third tactic was the introduction in 1966 of the Wild Weasel in conjunction with Iron Hand flights.<sup>39</sup> The F-100F Wild Weasel was a two-seat F-100 for a pilot and an electronic warfare officer (EWO). The EWO would operate the equipment used to passively identify and determine the bearing to enemy fire control radars. Once the Wild Weasel detected and initiated an attack against an SA-2, the pilot would descend down to low altitude to terrain mask<sup>40</sup> from the site. The Weasel would lead the Iron Hand flights to the SAM site at low altitude, popping up only as required to update the bearing to the site. If the Weasel obtained visual contact with the SAM site in enough time, the Weasel would mark the target with 2.75-inch rockets. More likely though, the Weasel would not obtain visual contact before over flight of the site. At this point the F-100F avionics would indicate station passage. The Weasel would then start a steep climbing turn followed by a diving attack on the site to mark it. The F-105 Iron Hand flights with their

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<sup>37</sup> Michael L. Michel III, *Clashes: Air Combat over North Vietnam 1965-1972* (Annapolis, M.D.: Naval Institute Press, 1997), 30.31.

<sup>38</sup> Benjamin F. Cooling, *Case Studies in the Achievement of Air Superiority*, (Washington DC: Air Force History and Museums Program, 1991), 531.

<sup>39</sup> *Ibid.*, 533.

<sup>40</sup> Terrain Masking involves using terrain to hide an airborne aircraft. In this case it US aircraft used terrain to hide from SAM radar operators. Radar cannot see over mountains or hills. Most radars require line-of-sight to the target. By using terrain masking US fighters could limit their exposure to the SAMs. However, terrain masking works the other way as well. Sensors used to track the SAM radar emissions were also affected by terrain masking.

hard-kill ordnance would then finish the job.<sup>41</sup> Although the Vietnamese could launch and guide the SA-2 optically until in its terminal phase at which time it needed to be radar guided, the Wild Weasel and Iron Hand flights still dramatically reduced North Vietnamese SAM effectiveness.<sup>42</sup>

In April 1966, the F-100Fs were first equipped with AGM-45 Shrike missiles. The Shrike negated the necessity to locate a SAM site by over flying it, thus reducing the threat caused by AAA at low altitude. However, the Shrike had its limitations. It had a maximum aerodynamic range around 17 miles, but it was not a fast missile (Mach 2.0) as compared to the SA-2 (Mach 3.5). This speed difference allowed the SA-2 to go through its entire firing sequence from launch through impact against an aircraft and shut down before a Shrike fired at maximum range could reach the SAM site. Therefore, the Weasels needed to move the employment range of the Shrike in to 12 miles. This put the Weasel in the heart of the SA-2 envelope and forced many threat reactions by the Weasels. The SAM operators also learned to detect an incoming Shrike. They would then simply shut off their radar to defeat the ARM.<sup>43</sup> Regardless of the limitations, the Shrike gave the F-100F Wild Weasels the ability to autonomously detect and engage SAM sites near them. SAM effectiveness dropped with the employment of the Shrike missile; in 1965, thirteen SAMs were fired for every downed aircraft; with Shrike equipped Wild Weasels, the number of required SAMs to down an aircraft more than doubled. Later with the retirement of the F-100s, the F-105 picked up the SEAD mission, initially with the Shrike and then subsequently with the Standard Anti-Radiation Missile (ARM).<sup>44</sup> The employment of the Wild Weasel tactics in conjunction with deception jamming employed by the US aircraft later in the war further reduced North Vietnamese SAM effectiveness. From 1965, when the first SAM was launched and the SEAD

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<sup>41</sup> William A. Hewitt, *Planting the Seeds of SEAD: The Wild Weasel in Vietnam*, (Maxwell AFB,

Ala.: Air University Press, 1993), 14-15.

<sup>42</sup> Benjamin F. Cooling, *Case Studies in the Achievement of Air Superiority*, (Washington DC: Air Force History and Museums Program, 1991), 533.

<sup>43</sup> William A. Hewitt, *Planting the Seeds of SEAD: The Wild Weasel in Vietnam*, (Maxwell AFB,

Ala.: Air University Press, 1993), 15-16.

mission was born, through March 1968, the ratio of SAMs fired to aircraft downed by them rose from 13:1 to 200:1.<sup>45</sup>

### **The Israeli Experience**

After the US withdrawal from Southeast Asia through the Gulf War of 1991, the Israelis were the only ones to employ US-built aircraft in a major conflict against Soviet-built air defenses. Their experience fighting surface-to-air missiles began like the U.S.'s against the Soviet-built SA-2. The Egyptians received the SA-2 from the Soviets in 1967, which the Israelis faced during the Six Day War. However, the Egyptian defenses were caught nearly unaware and the 160 SA-2s were ineffective, especially against low flying, maneuvering fighters. Toward the end of the War of Attrition in August 1970 the military support provided by the U.S. and the Soviets to Israel and the Arab countries respectively produced a continuous shift in advantage. As the Israelis battled for control of the skies with the Arab countries, every advance in technology was met with a counter. By the time of the 1973 Yom Kippur War, the Israelis were equipped with modern F-4 Phantoms and A-4 Skyhawks. However, they faced defenses comprised of an advanced SA-2, the SA-3, the SA-6, and the SA-7. Additionally, they faced the four-barreled, radar-controlled and power-operated ZSU-23-4 antiaircraft cannon. Together these weapons provided an air defense umbrella from the surface to a height of 72,000 feet and out to a range of 31 miles.<sup>46</sup> Unlike the US SEAD experience in Vietnam against a single threat, the Israelis were faced with an electronic warfare challenge across a wide spectrum of radio frequencies. Additionally, many of the radars could switch frequencies rapidly minimizing the effects of electronic counter measures (ECM).<sup>47</sup> The threat to Israeli aircraft was significant as they entered the Yom Kippur War.

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<sup>44</sup> Benjamin F. Cooling, *Case Studies in the Achievement of Air Superiority*, (Washington DC: Air Force History and Museums Program, 1991), 533.

<sup>45</sup> Ibid., 539.

<sup>46</sup> Ibid., 586.

<sup>47</sup> Ibid.

## **Yom Kippur War**

On 6 October 1973 Egyptian, Syrian, and Iraqi forces attacked Israel. Due to interior lines fighting over short distances, plus the advantage of a single centralized control, the Israelis were able to halt the Arab offensives. Later that day the Israelis began their counter-offensive. However, since they had not taken down the enemy SAMs, the Israeli air forces found themselves unable to support the needs of their ground forces. The Israeli fighter tactics were not sufficient to avoid or defeat the myriad of air defenses employed by the Arabs. They found themselves up against a wall of missiles that they could not penetrate and survive, therefore they changed tactics to one of trying to drain the Arab SAM inventories dry through fake and genuine attacks against SAM sites. By the end of the second day of the war the Syrian SAM batteries on the Golan Heights were silenced. The Egyptians, however, were more disciplined in their expenditure of missiles. Although, when they attempted a second offensive to relieve pressure on the Syrians, the Egyptian ground forces no longer had the mobile SAMs necessary to protect themselves. As they walked out from underneath the SAM umbrella, they were vulnerable to Israeli air power.<sup>48</sup>

Two weeks into the war the Israelis attempted another counter-offensive against the Egyptians. This time it was a combined arms effort that finally eroded the Egyptian's air defenses. Up until this point the Israeli Air Forces kept nibbling away at the SA-2s and SA-3s arrayed against them. However, it wasn't until the Israeli ground units started attacking SAMs with their long-range guns that holes were punched in the SAM wall. The last technological advance of the war was a series of new standoff weapons delivered to the Israelis from the U.S. Up to this point the primary standoff weapon was the Shrike. However, the Shrike had limited effectiveness against new Soviet-developed electronic counter-counter measures (ECCM). Weapons such as the rocket-propelled Bullpup missile, the TV-guided Maverick missile, the TV-guided Walleye bomb, and the Rockeye cluster munition all provided improved destructive power while increasing the standoff range as compared to standard ballistic weapons, and thus increasing aircraft survivability.<sup>49</sup> They also made limited use of the US-designed BGM-34-A RPV loaded

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<sup>48</sup> Ibid., 589-596.

<sup>49</sup> Ibid., 596-597.

with a Maverick missile.<sup>50</sup> The Israelis had great success employing these new weapons and gained valuable skills that would again be used a decade later.

## Bekaa Valley

In 1982, the Israelis invaded southern Lebanon to destroy Palestinian guerrilla strongholds. However, this resulted in an intense conflict between the Israeli and Syrian ground forces in the Bekaa Valley as the Syrians intervened to support the Palestinians. The Syrians set up a massive air defense barrier along the Syrian border on the eastern edge of the Bekaa Valley. The air defenses consisted of mobile SA-6s and SA-8s.<sup>51</sup> The Israelis realized that the only way they could establish air superiority over Lebanese airspace was to rid the area of the Syrian-manned SA-6 missiles, but they learned from the Yom Kippur War not to take these threats head on. They developed a plan that would combine manned and unmanned aircraft in an operation to expose and then attack the mobile SAMs.

The Israeli SEAD plan consisted of drones, surveillance aircraft, and Israeli manned fighters all working together. The Israelis used their RPVs to simulate fighter aircraft, thus stimulating the SA-6 and SA-8 batteries. Once the SAM radars became active the RPVs tracked their emissions and relayed the SAM locations to AWACS and E2-C aircraft. The Israelis then targeted the SA-6 radars with chaff-dispensing rockets while improved Shrike missiles were employed.<sup>52</sup> Israeli F-16s with additional protection from multi-frequency ECM pods then obliterated the now blind SA-6s and SA-8s with an assortment of weapons including Maverick missiles and laser-guided bombs (LGBs). In the first two hours of the attack the Israelis destroyed 19 SAM batteries while severely damaging 4 others. A month and a half later the Syrians tried once again to position SA-6s and SA-8s on the east ridge of the Bekaa Valley. However these were quickly identified and also destroyed by Israeli aircraft employing precision

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<sup>50</sup> Steven M. Shaker and Alan R. Wise, *War Without Men* (New York: Pergamon-Brassey's, 1988), 34.

<sup>51</sup> Benjamin F. Cooling, *Case Studies in the Achievement of Air Superiority*, (Washington DC: Air Force History and Museums Program, 1991), 598-599.

<sup>52</sup> Steven M. Shaker and Alan R. Wise, *War Without Men* (New York: Pergamon-Brassey's, 1988), 36.

standoff weapons.<sup>53</sup> The combined use of manned aircraft as shooters with drones to act as decoys during the Bekaa Valley conflict was a first in the SEAD mission. It set a precedent that influenced events almost a decade later during the Gulf War.<sup>54</sup>

## The Gulf War

The next major application of the SEAD mission was the US led coalition in the Gulf War. During the Gulf War, not only did the coalition face advanced SAMs as the Israelis had during their conflicts a decade earlier, but the SAMs were centrally controlled and coordinated in an advanced integrated air defense system (IADS). The underlying assumption behind the Coalition air campaign was the need to achieve air superiority early in the war. This meant the Coalition would have to suppress the Iraqi air defenses such that aircraft could operate in a fairly benign environment. The US-developed SEAD plan saw the centrally control IADS as both their strength and their vulnerability. Therefore, planners designed the Coalition air campaign to eviscerate the Iraqi air defenses.<sup>55</sup>

The problem facing the US planners of the Coalition air campaign was a daunting one. As opposed to the Syrian air defenses the Israelis faced in the Bekaa Valley in 1982, the Iraqi defenses were an order of magnitude greater in complexity, extent, and numbers.<sup>56</sup> The backbone of the Iraqi IADS was the French-designed KARI system. The KARI system provided the centralized command and control to the Iraqi leaders through a series of redundant nodes. Information flowing to and from individual air defense operators began at the Air Defense Operations Center in Baghdad through Sector Operations Centers (SOCs) and Intercept Operations Centers (IOCs) to the individual SAM and AAA batteries and early warning (EW) radars.<sup>57</sup> If the nodes could be disrupted, the SAM and AAA operators would be forced into an autonomous mode, a

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<sup>53</sup> Benjamin F. Cooling, *Case Studies in the Achievement of Air Superiority*, (Washington DC: Air Force History and Museums Program, 1991), 598-600.

<sup>54</sup> Michael R Gordon and General Bernard E. Trainor, *The Generals' War*, (New York: Little, Brown and Company, 1995), 112.

<sup>55</sup> Dr. Elliot Cohen, et al, *Gulf War Air Power Survey*, 5 vols. (Washington D.C.: U.S. Government Printing Office, 1993), 2:116.

<sup>56</sup> Ibid., 2:117.

mode they had little preparation for. Not only would they be less effective, they would also be more vulnerable to attack, since their radars would have to radiate to locate targets on their own. If the Coalition plan worked, they would not have to destroy every SAM site. By intimidating the SAM operators into leaving their radars off for fear of being targeted, the Coalition could operate at medium altitude with impunity, thus minimizing the AAA effectiveness.<sup>58</sup>

Unlike traditional SEAD plans that concentrated its efforts on the SAM and AAA shooters, the Coalition planned to take down the centralized control of the Iraqi IADS. This plan employed a myriad of aircraft and systems from the stealthy F-117 to the low and slow Apache helicopter. The initial attacks on the Iraqi IADS were conducted by F-117s and Tomahawk cruise missiles in and around Baghdad. They targeted the hub of the KARI system including command centers, communications facilities, and electrical facilities.<sup>59</sup> EF-111s were intended to provide jamming support to the F-117 strikes. However, in reality the first attacks were accomplished without any actual jamming support. The planned EF-111 support plus F-15Es that were to attack fixed SCUD missile sites in western Iraq needed a hole punched in the Iraqi EW network. CENTCOM decided on a helicopter raid made up of GPS-equipped USAF Special Forces Pave Low helicopters leading Army Apache helicopters to the EW radars. The Apaches then destroyed the radar vans with Hellfire missiles. This allowed the F-15Es and EF-111s to ingress to their targets undetected.<sup>60</sup>

The initial attack success was not based on stealth alone. The kickoff of the SEAD effort required a significant number of support aircraft such as AWACS, tankers, RC-135, etc. In order to prevent tipping off the Iraqis to the impending attack the Coalition developed a deception plan based on a fictional F-117 crash in Saudi Arabia.

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<sup>57</sup> Michael R Gordon and General Bernard E. Trainor, *The Generals' War*, (New York: Little, Brown and Company, 1995), 112.

<sup>58</sup> Dr. Elliot Cohen, et al, *Gulf War Air Power Survey*, 5 vols. (Washington D.C.: U.S. Government Printing Office, 1993), 2:118.

<sup>59</sup> Michael R Gordon and General Bernard E. Trainor, *The Generals' War*, (New York: Little, Brown and Company, 1995), 112.

<sup>60</sup> *Ibid.*, 119.

This cleared the airspace of civilian airline traffic and justified the increased military activity.<sup>61</sup>

Once the F-117s and Tomahawk missiles disrupted the air defense network with their first attacks, the full SEAD effort against Baghdad began. Not only did the initial attacks disrupt the IADS, it also implied an imminent all-out attack on Baghdad. This brought the Iraqi air defenses to full alert and readiness. To add to this illusion, the Coalition was massing aircraft just south of the Iraqi border resembling just such a raid. In reality, there were two massive SEAD packages inbound to Iraqi airspace.

The SEAD packages consisted of F-4G HARM shooters, EA-6B electronic jammers and HARM shooters, EF-111 jammers, and scores of unmanned drones. The drones, both BQM-74s and Navy Tactical Air Launched Decoys (TALDs) dropped from A-6s, were used to further increase the numbers of targets the SAM operators were seeing and entice the SAM operators into leaving their radars on. Up to the arrival of the drones the SAMs had been blinking on and off, thus not providing a consistent radar target for the HARM shooters. However, once the drones arrived over Baghdad there was a 22-percent rise in lethal radars attempting to acquire targets. Additionally, the presence of the airborne jamming forced the SAM operators to increase their radar power to burn through the interference. This further exposed the radars to detection and attack.<sup>62</sup>

At the same time as the raids on Baghdad, there were similar raids supported by drones against Scud bases in the west and around Kuwait City and Basra. These attacks achieved the same level of success in degrading the Iraqi IADS. As the Wing commander of the F-4Gs noted,

The key is that very early on while the F-15s maintained air superiority, the weasels maintained suppression of enemy air defense[s] as far as I am concerned, because they beat them down quickly, efficiently and the enemy knew if he turned his radars on, he'd be dead. As a result of that, they are not turning their radars on. If they do anything, they are blinking them off and on just to be able to say they are doing it and to maybe get some cuts on where the strikers are coming in. They're firing their missiles off ballistically. For the most part they are completely ineffective,

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<sup>61</sup> Ibid., 121.

<sup>62</sup> Dr. Elliot Cohen, et al, *Gulf War Air Power Survey*, 5 vols. (Washington D.C.: U.S. Government Printing Office, 1993), 2:128-133.

and I hold that almost exclusively at the value of suppression of the enemy air defenses during the first week.<sup>63</sup>

The results of the Coalition air campaign in the first 48 hours of the war were significant. The Iraqi IADS no longer operated as an integrated system. Many of the Iraqi radars and SAM sites were no longer functioning, either because they were destroyed or they were intimidated into not operating.<sup>64</sup> Regardless of the reason, the Coalition was able to operate at medium altitude with relative impunity. However, since the air defenses, especially mobile SAMs, were not completely attritted, subsequent strike packages would always include jamming and HARM shooter support.<sup>65</sup>

### **Operation Allied Force**

Operation Allied Force brought unique challenges to the SEAD mission. Although the threats employed by the Serbians were the same as those faced by the Coalition in the Gulf War, the Serbians learned from the Iraqi's experience and chose not to take NATO SEAD assets head on. Instead they routinely operated using tactics, such as on/off cycling, to degrade NATO HARM shots. Additionally, the Serbians moved their sites religiously to prevent US intelligence assets from pinpointing their locations with enough time to target them with hard-kill ordnance. However, the most significant change over previous conflicts was the fact that they never exposed many of their SAMs to NATO attack. This may have been due to lessons the Serbians learned from the Gulf War about US SEAD effectiveness or due to the Serbians intentionally trying to preserve air defense assets to employ once NATO's guard was down, or possibly both. Whatever the reason, NATO airmen had to be constantly on their toes, since the Serbian SAMs were never attritted and could appear at any time. This became evident with loss of an F-117 and F-16 to SAMs. The result of this was that although strike aircraft were not always threatened, there was a necessity for a full complement of NATO SEAD assets airborne to support every strike package.<sup>66</sup>

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<sup>63</sup> Ibid., 2:133.

<sup>64</sup> Ibid., 2:137.

<sup>65</sup> Ibid., 2:151.

<sup>66</sup> Zachary Lum, "The Deadly Game of SEAD," *Journal of Electronic Defense*, May 1999, 38-39.

The US SEAD aircraft used during Operation Allied Force were those that the U.S. learned to integrate during the last six years of the 20<sup>th</sup> century. They were the USAF F-16CJ, RC-135 Rivet Joint and AWACS, and the US Navy F-18, EA-6B, and EP-3. Unlike previous conflicts where the HARM shooters were essentially autonomous, the Air Force attempted to make them more effective by integrating SEAD, strike and ISR platforms through the sharing of targeting information over a real-time communications network.<sup>67</sup>

### **SEAD Entering a New Century**

As the U.S. enters the 21<sup>st</sup> century, its SEAD assets have matured significantly since the massive Coalition air campaign of the Gulf War only a decade before. Today the U.S. employs many aircraft that work together to provide a synergistic effect. Many of these assets were designed to perform a strategic or at best an operational mission. However, over the last decade many of them have been modified to provide a tactical role as well. With the proliferation of Russian “double digit” SAMs to any country with enough money, it is becoming more and more difficult to remain inside the enemy’s OODA loop.<sup>68</sup> It is this integration of assets that is maintaining the United States’ ability to execute effectively against an increasingly lethal air defense threat. The following paragraphs describe the United States’ primary SEAD assets. The author acknowledges that almost every aircraft or satellite can play a role in executing the SEAD mission in some fashion. However, this section is restricted to those aircraft that play a direct role in the reactive SEAD role for protection of airborne strike packages: the joint EA-6B, the Air Force’s F-16CJ and RC-135 Rivet Joint, and the Navy and Marine Corps’ F-18.

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<sup>67</sup> Ibid., 38.

<sup>68</sup> The OODA loop is a concept presented by John Boyd. OODA stands for Observation, Orientation, Decision, and Action. Eventually the side with the slower OODA loop will make inappropriate reactions to the situation. Therefore, whichever side repeats their OODA loop faster and more accurately will win. Col Phillip S. Meilinger, ed., *The Paths of Heaven: The Evolution of Airpower Theory* (Maxwell AFB, Ala.: Air University Press, 1997), 366.

## The Aircraft

The joint service EA-6B Prowler began service in the Navy as an electronic warfare version of the A-6 Intruder immediately following the Vietnam War. Following the retirement of the USAF EF-111 Raven in 1995, the EA-6B became a joint asset as the only radar jammer in the Department of Defense (DoD). It is a multi-mission platform coupling human interface with a sophisticated electronic warfare package. It has the primary mission of detecting, identifying and then jamming enemy radar emissions, as well as voice and data link signals. However, it also has the ability to employ the HARM. Although, by loading HARMs on its hard points, it must give up jamming pods. A typical loadout consists of one HARM and multiple jamming pods. This provides a balanced approach to the SEAD mission. The number of jamming pods can be increased or decreased as needed based on the enemy electronic order of battle (EOB). The necessity to have HARMs available on the EA-6Bs is directly related to the number of other HARM shooters in the SEAD package. Additionally, the EA-6B is being upgraded with the Improved Data Modem (IDM) providing the ability to share ELINT with other SEAD assets like the USAF F-16CJ.<sup>69</sup>

The Air Force's primary SEAD aircraft is the F-16CJ. The typical SEAD ordnance loadout contains two HARMs, but what makes the F-16CJ a more capable SEAD platform than the F-18 is the removable pod containing the AN/ASQ-213 HARM Targeting System (HTS) and the F-16CJ's Improved Data Modem (IDM). The HTS provides the ability to rapidly detect, identify, and generate ranges to enemy radars. With this information the F-16 can launch the HARM in its most effective mode.<sup>70</sup> The IDM provides the ability to share ELINT information with other flight members and to send and receive information from other off-board sources. At the time of the research for this thesis, the Air Force is planning an upgrade to the F-16CJ that will dramatically increase its capabilities. First, the F-16CJ will soon be upgraded with the Link16 data link, greatly

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<sup>69</sup> "EA-6B Prowler," *FAS Intelligence Resource Program*, 5 March 2000, n.p.; online, Internet, 15 March 2001, available from [http://www.fas.org/irp/program/collect/ea-6b\\_prowler.htm](http://www.fas.org/irp/program/collect/ea-6b_prowler.htm).

<sup>70</sup> "AN/ASQ-213 HARM Targeting System (HTS)," *FAS Military Analysis Network*, 4 March 2000, n.p.; online, Internet, 9 April 2001, available from <http://www.fas.org/man/dod-101/sys/smart/hts.htm>.

increasing the amount of information it can share. Second, an upgrade to the HTS, designated R7, will increase the F-16CJ's ability to engage enemy air defenses. R7 incorporates the ability to do multi-ship cooperative ranging of target radars, which significantly improves the F-16s ability to quickly and accurately range target radars. Additionally, it provides smaller target location errors permitting improved employment of hard-kill ordnance. R7 also provides improved signal discrimination, thus allowing the potential to update actual EOB. Third, software upgrades will allow the incorporation of a laser-designation targeting pod. With the targeting pod in conjunction with the smaller target location errors, the F-16 will have an improved ability to employ precision hard-kill ordnance on identified air defense sites. Together these upgraded capabilities provide significantly improved capability to find, pinpoint, and destroy mobile SAMs.<sup>71</sup>

The F-16CJ's partner in the SEAD mission is the USAF RC-135. The RJ as it is commonly known is a surveillance aircraft with an extensive array of sophisticated intelligence gathering equipment. Using both automated and manual systems, electronic and intelligence specialists precisely locate, identify, and analyze most of what is present in the electromagnetic spectrum. It can accomplish both its ELINT and COMINT missions at stand off ranges of up to 240 kilometers.<sup>72</sup> In the mid 1990s the RJ, like the F-16CJ, was outfitted with an IDM. This allows the sharing of ELINT information between the RJ, the F-16CJ flights, and eventually the EA-6B.

The other SEAD aircraft in the US inventory is the Navy and Marine Corps F-18. Like the F-16CJ, the F-18 can employ HARMs. However, it does not have the advantage of an HTS. It is limited to preplanned shots against input latitudes and longitudes, or reactive shots using the HARM without a known target location. Although this can still be a successful employment mode, it is not as effective as employing against a range known target radar. The Navy is looking at ways to bring the reactive range-known capability to the F-18.

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<sup>71</sup> "Block 50/52 Targeting Pod Requirements," *FAS Military Analysis Network*, 27 September 1999, n.p.; online, Internet, 9 April 2001, available from <http://www.fas.org/man/dod-101/sys/smart/docs/atp-F16CJreq/tsld.001.htm>.

<sup>72</sup> "Rivet Joint," *FAS Intelligence Resource Program*, 5 March 2000, n.p.; online, Internet, 9 April 2001, available from [http://www.fas.org/irp/program/collect/rivet\\_joint.htm](http://www.fas.org/irp/program/collect/rivet_joint.htm).

## The Weapon

Although almost any weapon could be employed in the SEAD role, the HARM continues to be the primary SEAD weapon in the US ordnance inventory. The AGM-88 HARM is a supersonic air-to-surface missile designed to home on enemy radar air defenses and disable them. It has the ability to discriminate a single threat from a number of other emitters in the tactical environment. It entered the USAF inventory on March 1983 on the F-4G. Since then it has been operationally deployed throughout the Air Force, and is in full production as a joint US Air Force / US Navy project. Additionally, several NATO partners have acquired the HARM for their aircraft.<sup>73</sup> The HARM continues to prove its worth against continuously emitting threat radars.<sup>74</sup> However, the HARM is not the perfect weapon.

There are some limitations to the AGM-88 HARM. Although an anti-radiation missile has unique abilities to home in on enemy emitters and disrupt or destroy the elements of an IADS, they are not classic precision-guided weapons, such as LGBs.

On the contrary, ARMs cannot be steered and under certain conditions may not guide on the target that they were originally fired. Also they do not have the ability to discern friend from foe. Therefore, the precision detection capability of the launching platform and its human operator in the loop are key elements ensuring weapon effectiveness and the prevention of fratricide. The translation of what the launching aircraft sees to what the ARM sees is paramount.<sup>75</sup>

Additionally, as both allies and enemies employ more and more radars, it becomes increasingly difficult to resolve ambiguities between systems. Many of the systems employ radars operating with overlapping radar characteristics. Furthermore, the proliferation of like systems on both sides of a conflict makes this problem even worse. For example, during the Gulf War, both the Coalition and the Iraqis employed the SA-6 and Hawk SAMs. This intermingling of systems during changing world political conditions and overlapping of operating spectrums makes it increasingly difficult to

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<sup>73</sup> "Luftwaffe Looks at HARM to Maintain SEAD Lead," *Jane's International Defense Review*, January 2000, 63.

<sup>74</sup> "AGM-88," *FAS Military Analysis Network*, 23 April 2000, n.p.; online, Internet, 8 April 2001, available from <http://www.fas.org/man/dod-101/sys/smart/agm-88.htm>.

<sup>75</sup> *Ibid.*

determine friendly, enemy and neutral radar emissions.<sup>76</sup> A thorough understanding of the EOB, both friendly and enemy, by the human operator is now more than ever critical to HARM employment.

### **Other SEAD Assets**

As mentioned earlier, the assets mentioned above are not the only SEAD players. There are some of the additional players in the SEAD game such as other collection assets. However, they do not directly feed the shooters. They currently feed the various military networks, which are received either by the RJ, AWACS, or ground station. They in turn feed the information to the shooters through voice communications or the IDM.

### **Conclusion**

The aircraft and air defense game of response versus counter-response has been going on since the introduction of aircraft into war. AAA was initially the most feasible ground-based defense against the aircraft. It was relatively inexpensive, thus it could be produced in mass numbers. This mass offset the relatively poor efficiency of the individual AAA pieces. As early as World War II, the Germans attempted to increase the lethality of ground-based defenses by developing a surface-to-air missile. However, the technology to provide guidance to a SAM did not yet exist. Although SAMs engaged US U-2 aircraft in 1960, it wasn't until the Vietnam War that the U.S. had to face radar-guided SAMs in significant numbers. This instigated the creation of the specialized aircraft to execute the SEAD mission, which continues today with improved capabilities to counter advances in air defenses.

Today the U.S. employs a variety with unique capabilities focused toward the SEAD mission. Instead of concentrating on advanced aircraft designed to execute the SEAD mission alone, the U.S. has integrated their SEAD assets to provide a synergistic effect and maintain an advantage over enemy IADS. The challenge will be to maintain this advantage into the next decades as potential enemies continue to develop increasingly lethal surface-to-air threats.

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<sup>76</sup> Ibid.

## Chapter 4

# THE THREAT

### Introduction

Potential enemies of the U.S. have watched as US led coalitions and alliances have dominated the skies over Iraq, Bosnia, and Serbia. What they have learned is that the U.S. is determined to establish air superiority over its enemies as an enabler for all other missions. They also have learned that few countries have the advanced aircraft or the training required to challenge US airpower head to head. This drives them toward continued advances in counter responses in order to challenge US air dominance. This appears in the development and proliferation of new and increasingly lethal surface-to-air missile systems.

The capabilities of future SAMs pose a significant threat to the ability of US SEAD assets to be effective while being survivable. Many of these threats are designed to counter the strengths of the US SEAD effort, mainly stealth and weapons that provide stand off radar homing. Many of the most lethal SAMs continue to be produced by the Russians and are available for export to almost any country. The following section describes some of the newest and most lethal SAMs developed by the Russians: the short-range SA-11 and SA-17, and the longer-range SA-10, SA-12, and SA-20.

### The SA-11 Gadfly (Gang)

The SA-11 Gadfly is classified as a short-range surface-to-air missile. The Russians began development of the SA-11 (Russian designation ‘Gang’) in the early 1970s as a replacement for the SA-4 Ganef and the SA-6 Gainful. The SA-4, which became operational in 1967, had a reputation for being hard to maintain. The main

shortcoming in the SA-6 was reliance on a single engagement radar for each battery of four launch vehicles. This created a vulnerability that the Israelis took advantage of during the Yom Kippur War in 1973. The initial Russian response was the introduction of the SA-8 to complement the SA-6. However, the SA-8 was too short range to compensate for the SA-6 vulnerability. The SA-11 provided the reliability not present in the SA-4 and had an engagement radar associated with each missile launch vehicle, thus avoiding the SA-6 vulnerability.<sup>77</sup>

The SA-11 became operational in 1977. However, the Russians encountered problems with the SA-11's missile. Therefore, it was first fielded using the SA-6 missile. Eventually the problems with the missile were solved, and the Russians fielded the complete system in 1979. The SA-11 went through an upgrade in the late 1990s designated Buk-M1-2. This upgrade increased the range of the SA-11 system by incorporating the SA-17's missile<sup>78</sup>, which is discussed in the next section.

The SA-11 is a very capable SAM. The original SA-11 missile had a minimum range of 3km and a maximum range of 35km at altitudes from 15m to 22km. The missile guidance is inertial with command updates in mid-course and semi-active radar in the terminal phase. For its terminal guidance it relies on continuous wave illumination from the 'Fire Dome' engagement radar. The upgraded version of the SA-11 has a maximum range of 45km and a maximum altitude of 25km. A typical SA-11 battery is made up of a command post, a surveillance radar, six transporter-erector-launcher and radar (TELAR) vehicles equipped with four missiles each, and three loader-launchers. Therefore, each battery includes 48 missiles. Each component is mounted on a tracked vehicle providing mobility. Due to the SA-6 vulnerability, the Russians designed the SA-11 to be more survivable. Each component of the SA-11 system can be dispersed up to 5km. Additionally, if necessary, each TELAR can operate autonomously. In addition to the illumination radar each TELAR is also equipped with a TV tracker with laser range-finder for use in ECM conditions.<sup>79</sup> According to the Russians the SA-11 has a single

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<sup>77</sup> Duncan Lennox, ed., *Jane's Strategic Weapon Systems*, 34<sup>th</sup> ed. (Alexandria, VA: Jane's Information Group, 2001), 306.

<sup>78</sup> Ibid.

<sup>79</sup> Ibid., 306-307.

shot probability of kill of 0.6-0.9 against aircraft, 0.3-0.7 against helicopters, and 0.4 against Tomahawk-class cruise missiles.<sup>80</sup>

The SA-11 Gadfly has been exported to many countries. In addition to the former Soviet countries of Belarus and Ukraine, it has also been exported to Finland, India, Poland, Syria and the Federal Republic of Yugoslavia.<sup>81</sup>

### **The SA-17 Grizzly (Russian designation ‘Ural’)**

The SA-17 is a follow-on to the SA-11 Gadfly short-range SAM. The SAM system was designed to counter aircraft, helicopters, tactical ballistic missiles, cruise missiles, air-to-surface missiles, and UAVs. The system began development in 1983 and became operational in 1995. A new version of the SA-17, designated ‘Mysk’, now in development employs a new missile with delta-wings for improved maneuverability against low-level targets. Additionally, a new version of the SA-17 was developed for export that has the components on wheeled vehicles versus the original tracked vehicles. The system was offered for export in 1993.<sup>82</sup>

The SA-17 has improved capabilities over the SA-11. The SA-17 has a minimum range of 3km and a maximum range of 50km at altitudes from 10m to 25km. Its guidance is the same as the SA-11. Like the SA-11, the SA-17 has capabilities in an ECM environment. However, it uses a more capable electro-optical tracker versus the SA-11 TV tracker. The SA-17 battery consists of a command vehicle, a surveillance radar vehicle, four TELARs and four loader/launcher vehicles. The command system can track up to 260 targets and control up to six TELARs engaging up to 36 targets.<sup>83</sup>

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<sup>80</sup> “SA-11 Gadfly, 9K37M1 BUK-1M,” *FAS Military Analysis Network*, 20 June 2000, n.p.; on-line, Internet, 12 January 2001, available from <http://www.fas.org/man/dod-101/sys/missile/row/sa-11.htm>.

<sup>81</sup> Duncan Lennox, ed., *Jane’s Strategic Weapon Systems*, 34<sup>th</sup> ed. (Alexandria, VA: Jane’s Information Group, 2001), 308.

<sup>82</sup> *Ibid.*, 316-317.

<sup>83</sup> *Ibid.*, 317.

## **The SA-10 Grumble (Russian designation S-300 / S-300 PMU)**

The SA-10 Grumble is classified as a short to medium range, ground-based, theater defense missile. It was designed in the 1960s, and developed in the 1970s, but has seen significant improvements throughout its lifetime.<sup>84</sup>

The SA-10 was initially designed as a high altitude surface-to-air missile also capable of engaging larger air-to-surface missiles. Later in the 1970s the Russians also added the requirement to engage low-flying aircraft and missiles. Therefore, the illumination radar can be elevated on a 24m tower for increased capability against low altitude targets.<sup>85</sup> The operational version, the SA-10A (S-300 P) entered service in 1980 with an effective range of 45km. The SA-10B (S-300 PM) entered service in 1982 and employed an improved missile with a range of 75km. The SA-10C (S-300 PMU) entered service in 1985 with a missile capable of engaging at 90km, and the SA-10D (S-300 PMU1) became operational in 1992. The SA-10D incorporated several modifications to the radars and the command and control center, as well as a new missile. These improvements gave the SA-10D a range of 150km. The newest version, the SA-10E (S-300 PMU2), employs a missile capable of 200km, and incorporates a new surveillance radar. The Russians offered this system for export in 1998. Additionally, there are unconfirmed reports that the Russians have developed an active radar seeker for terminal guidance; however, it has not yet been offered for export. The SA-10 Grumble has a similar capability to the MIM-104 Patriot system, but with significantly increased range.<sup>86</sup>

## **SA-12 Gladiator/Giant (Russian designation S-300V)**

The Russian S-300V has the NATO designation SA-12 Gladiator/Giant. The SA-12, like the SA-10, is classified as a short to medium range, ground-based, theater

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<sup>84</sup> Ibid., 302-305.

<sup>85</sup> “S-300PMU, SA-10 Grumble, SA-N-6 Grumble, HQ-10/15 (Chinese licensed copy),” *FAS Nuclear Forces Guide*, 30 June 2000, n.p.; on-line, Internet, 12 January 2001 available from <http://www.fas.org/nuke/guide/russia/airdef/s-300pmu.htm>.

<sup>86</sup> Duncan Lennox, ed., *Jane’s Strategic Weapon Systems*, 34<sup>th</sup> ed. (Alexandria, VA: Jane’s Information Group, 2001), 302-305.

defense missile. It is a tracked vehicle based on the T-80 tank chassis designed to defend mobile forces. The Russians initially designed the SA-12 to counter high altitude bombers and the entire spectrum of heavy high value airborne assets (HVAA) the U.S. employs including tankers, AWACS, Rivet Joint, etc. Additionally, it was designed to intercept ballistic missiles and low-altitude cruise missiles.<sup>87</sup>

The SA-12 system employs multiple radars and two missiles types. The Gladiator missile, the SA-12A, is the smaller of the two missiles and has been optimized for aircraft and air-to-surface missile interceptions. The Giant, the SA-12B, is thought to be optimized to intercept short and intermediate range ballistic missiles. It is also believed that the SA-12B has been modified to perform better against low-altitude cruise missiles. The guidance for the SA-12 is similar to that of the SA-10. It uses inertial guidance with mid-course command updates, and then track-via-missile semi-active radar in the terminal phase. The Russians may also be developing an active radar for terminal guidance of the Giant missile. This will improve its capability against smaller radar cross section (RCS) targets. The SA-12A Gladiator has a minimum range of 7km and a maximum range of 75km against aircraft targets at altitudes between 25m and 25km. Against short range ballistic missiles it has only a maximum range of 25km due to the high line of sight rate intercept created by the high velocity of the ballistic missile. The SA-12B Giant has better range performance because of its larger size. It can engage aircraft targets from a minimum range of 13km out to a maximum range of 100km at altitudes from 250m up to 30km. It can engage ballistic missiles between 20km and 40km at altitudes between 2km and 25km.<sup>88</sup>

An SA-12 battalion is made up of two major components, the Target Detection and Designation Station and the Fire Unit. The Target Detection and Designation Station consists of a Mobile Command Post, a surveillance radar (NATO designation ‘Bill Board’), and a sector scanning radar (NATO designation ‘High Screen’). The Fire Unit consists of four batteries each containing an engagement radar/battery command post (NATO designation ‘Grill Pan’), six transporter-erector-launcher and radar (TELAR), and six transloaders. Each TELAR carries six missiles varying between the two types.

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<sup>87</sup> Ibid., 309-310.

<sup>88</sup> Ibid., 310-311.

Therefore, the total missiles in a battalion can vary between 96 SA-12B and 192 SA-12A.<sup>89</sup>

The SA-12 system provides a country with lethal defense reaching well into their enemy's territory. Every component is mobile, based on the T-80 tank chassis. This indicates the intentions to deploy the SA-12 near the forward edge of the battle area. The surveillance radar provides 360° coverage out to 300km in range and 30km in altitude. It can track up to 200 targets, which it hands off to the command post. The sector scanning radar also feeds the command post, but is not used for aircraft. It is used to target ballistic missiles with their significantly higher velocity. The mobile command post controls the entire system, initiates track, and then tracks up to 70 targets. It then automatically distributes up to 24 aircraft or 16 ballistic missile targets among the four battery fire units. Each engagement radar then tracks the designated targets out to a range of 150km and controls the operation of six launchers. It also provides the data for launch and guidance. Each TELAR then has its own target illumination and command radars. Adding to its survivability, the SA-12 system's missile launch vehicles can be ready to fire five minutes after reaching a pre-surveyed site. Following missile fly-out they can be back on the move again in another five minutes. Additionally, the Russian air defense forces have demonstrated the ability to network from 15 to 20 SAM batteries, thus sharing target allocation, which cuts down on redundant targeting and excessive exposure to anti-radiation missiles.<sup>90</sup>

The SA-12 was first offered for export in 1992. Since then it has been exported to Belarus and Ukraine. Additionally, the Russians have deployed missiles to Armenia in 1999 as part of an integrated air defense for the Russian Federation and its partner countries. Furthermore, India ordered six battalions of SA-12s in 1998 for integration with their existing medium range SAMs.<sup>91</sup>

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<sup>89</sup> Ibid.

<sup>90</sup> Ibid., 311-312.

<sup>91</sup> Ibid., 312.

## The SA-20 (S-400)

In early 2001, Russia began testing on its newest long range SAM system. It is scheduled to become operation toward the end of 2001. The SA-20 Triumph is essentially an advanced derivative of the SA-10C (S-300 PMU), and is intended to replace the S-300 and the older S-200 SAMs.<sup>92</sup> The SA-20 is designed to engage the entire gamete of current and future air threats including fighter and bomber aircraft, cruise missiles, ballistic missiles, as well as AWACS and other standoff HVAA.<sup>93</sup> The Triumph can employ any of the older S-300 missiles, but it is the new missiles being designed in conjunction with its multifunction radar that provides the significant improvements over the S-300. Like the SA-12, the SA-20 system will employ two missile variants, one medium-range and one long-range. The medium-range missile variant has a maximum range of 120km, while the long-range missile has a maximum range of 400km. The new missile in the Triumph system will feature a combination of semi-active and active terminal guidance.<sup>94</sup> The Russians claim the medium-range missile will have a 0.9 probability of kill ( $P_k$ ) against piloted aircraft and a 0.8  $P_k$  against maneuvering unmanned aircraft and missiles at altitudes as low as 5m and as high as 35km. This capability is provided by a gas dynamic missile flight control system. It allows the missile to maneuver with a load factor of 20g at altitudes as high as 115,000ft (35km). In addition to providing an incredible anti-aircraft capability, this maneuverability provides an effective capability against ballistic missiles and cruise missiles. The Russians also claim the SA-20 has significant capability against low observable (stealth) technology. The long-range missile with its 400km launch range has over-the-horizon capability, and though it has similar capabilities as the medium-range

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<sup>92</sup> Sergei Babichev, "Triumph Advances to Firing Line," *Military Parade*, May-June 1999, n.p.; on-line, Internet, 21 March 2001, available from <http://milparade.com/1999/33/012.htm>.

<sup>93</sup> "Russian S-400 Triumph SAM System Undergoes Trials," *Venik's Aviation – Aerospace News and Technical Information*, March 2001, n.p.; on-line, Internet, 21 March 2001, available from <http://www.aeronautics.ru/s400triumph.htm>.

<sup>94</sup> "Russia Tests Triumph Long-Range SAM System," *NBCi*, March 2001, n.p.; on-line, Internet, 21 March 2001, available from <http://members.nbc.com/082499/aviation/s400triumph2.htm>.

variant against smaller, more maneuverable aircraft, its long range optimizes it for attacking AWACS, and other HVAA.<sup>95</sup>

## Conclusion

In recent conflicts the U.S. has shown its ability to dominate the skies. Potential adversaries are not looking to take the U.S. on head to head in the air. Instead they have developed counters to U.S. air dominance through advanced air defense systems. These improvements threaten the United States' technological edge. As the Russians, as well as others, field more and more lethal air defenses and proliferate them throughout the world, the U.S. needs to take another technological leap to maintain that air dominance edge.

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<sup>95</sup> Sergei Babichev, "Triumph Advances to Firing Line," *Military Parade*, May-June 1999, n.p.; on-line, Internet, 21 March 2001, available from <http://milparade.com/1999/33/012.htm>.

# **Chapter 5**

## **SEAD SOLUTIONS**

### **Introduction**

As evident from the previous chapter, the Russians have continuously been improving their air defenses to counter US aircraft advances. This trend has continued with the advances apparent in the SA-20 as they recognize the challenges posed by US stealth and advanced weapons developments. Other countries have followed this trend as well, developing systems with similar capabilities. As these systems proliferate throughout the world, the potential for the U.S. and its allies to have to face these threats is increasing. The challenge for the U.S. is to develop SEAD technology that will maintain an advantage over fielded air defense systems. The Air Force is looking to implement a technological solution by 2015; therefore, the decision on the route to take will be made in fiscal year 2005-2007. The three possible solutions being studied for the SEAD mission are developing a space-based SEAD capability, modernizing current manned aircraft and weapons, or employing a UCAV force.<sup>96</sup>

### **Space-Based SEAD**

This section does not attempt to present an in-depth discussion of all the factors impacting the development of space-based weapons to execute the SEAD mission. Instead, it explores the pros and cons of attempting to go down that road. Many of the issues involve international treaties and therefore may be beyond the control of the Air

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<sup>96</sup> David R. Honeywell, Senior Systems Analyst, HQ USAF/XORR, "UAV & UCAV Update," presentation, Checkmate 2001 Strategy Conference, Arlington, VA, 22 February 2001.

Force. However, there is a potential for a space-based SEAD capability that cannot be ignored.

Before discussing the pros and cons the reader must understand the possible space options. First, there are two different categories of space platforms. They are space-based platforms, and space-borne platforms.<sup>97</sup> Space-based platforms are those that once launched continuously reside in space. Communications and surveillance satellites fall into this category. These are the assets discussed in this thesis. Space-borne platforms vary from space-based platforms in that they only temporarily occupy or transit space, such as intercontinental ballistic missiles (ICBMs). They are not discussed further, since they offer little to the reactive SEAD mission due to their inability to loiter over the threats.

The space-based platform is the most responsive, because it operates immediately from the high ground of space. Possessing the unique perspective of space, space-based weapons can immediately cover a large theater of operations. This potential advantage grows as the platform's orbital altitude is increased, reaching its peak with platforms placed at geosynchronous orbit, which effectively provides access to almost half the earth's surface from a single platform. Of course, the higher the orbit, the farther the platform is from its targets. Alternatively, if the platform can be placed in low earth orbit (LOE), the range to the target can be minimized at the cost of reduced ground (and time) coverage for each platform. Given the immense volume of near-earth space, a space-based constellation can consist of many platforms, providing reliability through redundancy. A weapon system with enough space-based platforms at the proper orbital altitude(s) can potentially ensure global, full-time coverage and provide the ability to conduct prompt and sustained operations anywhere on the planet.<sup>98</sup>

There are several different types of possible space-based weapons that have utility for SEAD weapons. They range from incoherent and coherent light, neutral particle beam, high-powered microwave, and projectile weapons. Each of these weapons has its own capabilities, limitations, and fielding challenges, and is beyond the scope of this thesis. However, a brief description of each follows.

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<sup>97</sup> Lt Col Jamie G. Varni, et al., "Space Operations: Through the Looking Glass," *Air University Report*, August 1996, n.p.; on-line, Internet, 12 January 2001. available from <http://www.au.af.mil/au/2025.htm>.

An incoherent light weapon uses light from the sun and aims it at a specific point on the Earth through space-based mirrors. It has the potential to create enough heat to melt objects on the Earth. However, a significant number of large mirrors would be necessary to create this effect. The biggest advantage to this system is an endless source of energy.<sup>99</sup>

Coherent light weapons are also known as lasers. Laser energy from space could either come from a space-based laser or from a ground-based laser reflected off a space-based mirror. Lasers of incredible power would have to be employed to counter the long slant ranges and atmospheric attenuation resulting from the large slant ranges. Additionally, lasers are not all-weather weapons. They dissipate and distort through clouds. A major constraint on space-based lasers is refueling. These high-powered lasers would draw huge amounts of fuel. Refueling these space-based lasers would be very expensive, as the fuel would have to be lifted to the satellite. A possible solution to this problem is by developing solid-state or diode laser systems that can be configured to operate on electrical power, and thus could easily be recharged. However, significant advances will need to be made in electrically powered lasers, since these systems can currently only generate small amounts of energy.<sup>100</sup>

A Neutral Particle Beam (NPB) is another type of directed energy weapon. It is created by forming a stream of high-speed-neutral atomic particles. These particles deliver their kinetic energy directly into the atomic and subatomic structure of the target, literally heating the target from deep within. To develop a weapons class NPB, the weapon would have to generate millions of volts of electrical potential, thus a huge power supply. Additionally, they would require large magnetic fields for beam direction, and require massive accelerators weighing hundreds of tons, thus requiring significant advances before being feasible.<sup>101</sup>

A High Powered Microwave weapon employs a directed flood of electromagnetic radiation. Microwave wavelengths are used since the atmosphere is generally transparent to them, and most electronic equipment is very sensitive to them. This type of weapon

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<sup>98</sup> Ibid.

<sup>99</sup> Ibid.

<sup>100</sup> Ibid.

would have the same effect on electronics as a nuclear electromagnetic pulse; however, it would be much more localized to the beam width of the microwave. The challenge is focusing the beam. A space-based microwave would have to have an antenna or array of antennas measured in acres. The size of this weapon creates significant challenges to implementation.<sup>102</sup>

Kinetic Energy Projectile weapons have great destructive power. Several hundred containers of small projectiles can be orbited until need. At that time the projectiles can be fired from the satellite at targets on the Earth. The reentry speed guarantees significant destructive power upon impact. However, like the chemical laser weapon, a kinetic energy weapon would need to be replenished. Additionally, it would have only one level of lethality, total destruction of what it hits.<sup>103</sup>

## **Capabilities and Limitations**

There are advantages and disadvantages to using a space-based platform for executing the SEAD mission. A space solution has the potential of unparalleled responsiveness, as compared to aircraft. With a robust constellation of assets in orbit, space-based platforms can respond immediately. There is no wait for mobilization of personnel and equipment. The assets can provide global coverage, and thus are already present over the theater of operations. However, the necessity for a robust constellation of satellites is also a disadvantage. The lift required to put the constellation in orbit is very expensive and time consuming. Additionally, space-based platforms are very difficult to service and maintain due to their inaccessibility. Furthermore, since orbits are easy to predict and track, an enemy would be able to anticipate and exploit any gap in coverage over the theater.<sup>104</sup> With potential gaps in the satellite coverage, the space-based SEAD support assets would drive the timing of strike packages already constrained by Navy carrier deck cycles, aircraft turn times, weather, etc. An additional consideration is that if the U.S. becomes heavily reliant on these satellites for SEAD, they

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<sup>101</sup> Ibid.

<sup>102</sup> Ibid.

<sup>103</sup> Ibid.

<sup>104</sup> Ibid.

become a high-value target, which is exposed to a determined adversary's attack.<sup>105</sup> Range from the threat to the SEAD asset is also a concern with space-based systems. As the range from the radar emitter increases, the size of the error ellipse increases. This has been a problem with current day ELINT assets if they must standoff from the target.<sup>106</sup> A way around this is to triangulate the emitter position through multiple ELINT assets from different angles. However, even with triangulation, the ranges of even low-Earth orbit may make geo-location too inaccurate to aim a precision-guided weapon. Other sources of data, such as imagery or SAR, may have to be fused with the ELINT data to provide the accuracy necessary. These are just the tactical and operational considerations to employing a space-based SEAD capability. There are also significant strategic issues that must be addressed.

## Implications

In addition to the considerations above, there are far-reaching implications to weaponizing space. Even if the U.S. intended to field space-based weapons for the sole purpose of executing the SEAD mission, the potential to use these weapons to attack a whole array of other targets exists. This includes Russian and Chinese ballistic missiles. The ability of the U.S. to over-fly any point on the Earth and employ destructive power at any time would be very destabilizing. Additionally, there are many senior leaders in the U.S. and abroad that support David Lupton's sanctuary space doctrine. The sanctuary doctrine was built on the concept of "open skies" and space for peaceful purposes first put forth by President Eisenhower. "Sanctuary doctrine advocates believe that overflight and remote sensing enhance stability and that space must be kept a weapons-free zone to protect the critical contributions of space surveillance systems to global security."<sup>107</sup> Additionally, it would follow that as soon as the first country places weapons in orbit, others would soon follow suit. In the 1950s President Eisenhower was concerned over the Russian reaction to overflight of their country by US surveillance satellites, as they

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<sup>105</sup> Ibid.

<sup>106</sup> Lt Col Walzel, Jay White, and Maj Patrick Moore, interviewed by author during visit to JSEAD, Nellis AFB, Nev., 8 March 2001.

<sup>107</sup> Peter L. Hays, et al., ed. *Space Power for a New Millennium: Space and U.S. National Security* (New York: McGraw-Hill, 2000), 3.

had over surveillance aircraft. However, once the Russians launched Sputnik, the issue was void and the U.S. began launching their satellites to provide intelligence formerly unavailable. Following this logic, if the U.S. placed weapons in space, the sanctuary would be violated. Now other countries could place weapons in space that would have the ability to employ force over the territorial United States, without any grounds for U.S. protest.

In summary, the space-based weapon has its one main advantage, responsiveness. However, an ability to quickly get a SEAD capability to a theater is not critical, if the aircraft requiring SEAD are not yet in theater. Additionally, there are many challenges to employing a space option that reach well beyond the SEAD mission.

## **Modernized Aircraft and Advanced Weapons**

The second option the Air Force is considering for the 2015 SEAD mission is modernized manned aircraft employing advanced weapons. This option builds on known capabilities and airframes to counter the increasingly lethal surface-to-air threat. The key to an effective reactive SEAD platform is responsiveness when the strike package is being threatened. This puts certain constraints on the way the SEAD aircraft must be employed. For example, with the speed of current and future SAMs, the SEAD aircraft can not standoff at a great distance and have any hope in engaging the SAM site before it times out its missiles against friendly aircraft. For this reason, it is critical that the SEAD aircraft be maneuverable and stealthy enough to operate inside the maximum range the various SAMs and survive. This significantly shortens the time of flight of any weapon employed against the SAM site. Additionally, by operating in this region the aircraft is also close enough to reduce the error ellipse of any on-board ELINT collection and identification system. Due to the anticipated lethality of air defenses in 2015, current US aircraft are not sufficient to operate inside the maximum kinematic range of these systems. Additionally, by 2015 most current US SEAD aircraft will be reaching the end of their life cycle, and thus will need to be replaced.

For these reasons the Joint Strike Fighter (JSF) has great potential to take over the manned SEAD role. The JSF incorporates advanced electronic support systems that can

provide the ability to take over the mission currently accomplished by the F-16CJ HTS. However, JSF's stealth and maneuverability allow it to operate in the advanced air defense threat envelope and survive. In many ways the capabilities of the JSF closely resembles the technology incorporated in the UCAV described in the next section. The difference is the level of human interaction.

Another factor in the modernized aircraft option is the pilot in the cockpit. By having the pilot in the cockpit, the final decision to employ ordnance is made by a human that can check the electronically generated information against the outside world. The operator in the air has a unique perspective that can help prevent fratricide, reprioritize tasks based on the dynamic combat environment, and respond to unexpected situations. However, there is a down side to having operators in the cockpit.

There are several disadvantages to having a manned-aircraft execute the 2015 SEAD mission. First, manned aircraft open up the risk of losing a pilot and/or weapons systems officer if the aircraft is shot down. This is increasingly likely if the SEAD aircraft must operate inside the threat envelope in order to be effective. Additionally, manned aircraft have the added expense and complexity to provide life support and pilot-to-vehicle interface, which includes the ability to employ and fly the aircraft, and the displays to present information to the pilot in a coherent manner. In fact, the rising cost of providing pilots with all of the crucial information along with the stealth and maneuverability to survive has exponentially increased the cost of manned aircraft to the point that they may become unaffordable if the trend continues. The aircraft also cannot be designed to exceed the pilot's physical limitations. This limits the number of Gs that can be pulled and also the way in which the aircraft maneuvers. The cockpit also affects the low observability. There are many characteristics of a cockpit, including sharp metal corners, switches, instruments, etc., that reflect electromagnetic energy well. Lastly, the operation and support (O&S) costs of employing a manned aircraft are traditionally very high. Pilots and Weapons Systems Officers need to fly their aircraft to maintain their combat proficiency. Even though the Air Force is fielding advanced simulators that allow multi-ship employment, there will still be a need to get real-world flight training. No other way can the effects of G and maneuver on the body be combined with the data

management skills learned in the simulator. In addition to advanced aircraft, new weapons offer improved effectiveness and survivability against the future threat.

## **Advanced Weapons**

Advanced weapons also promise to increase the effectiveness of SEAD aircraft while enhancing their survivability. An advanced version of the HARM proposed by the US Navy and designated Quick Bolt offers an increased responsiveness by reducing the time from sensor to shooter. Quick Bolt takes advantage of initiatives in the Tactical Exploitation of National Capabilities (TENCAP) program. As part of the TENCAP program the Space Warfare Center studied ways to get real-time information to and from the cockpit under the program Talon Shooter. One of things Talon Shooter demonstrated was the ability to relay information from space systems directly to fighter cockpits in near-real time. The information passed was the location and type of a surface-to-air missile (SAM) site. This information was passed from the aircraft to the HARM, which was fired and scored a hit on the site. This was without the actual aircraft ever detecting the threat.<sup>108</sup> This demonstrated capability is what instigated the concept behind the Quick Bolt initiative.

Quick Bolt takes the basic HARM hardware and modifies it to communicate with National assets, thus negating the necessity for an on-board sensor like the F-16CJ HTS.<sup>109</sup> Most of these modifications are in the seeker and guidance sections. In place of the original HARM guidance unit is a multi-mode seeker. This multi-mode seeker contains a millimeter wave (MMW) radar, a GPS-aided inertial navigation system, an anti-radiation homing (AHR) receiver, and embedded national tactical receiver and a transmitter. The GPS-aided INS provides mid-course guidance and also supports sensor fusion with off board data. This is used in the geo-location of the threat. The passive AHR receiver accomplishes the Quick Bolt's autonomous target detection, identification, tracking and target ranging. Its field of view, sensitivity, direction finding accuracy, and processing power all exceed current HARM capabilities. The active MMW radar

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<sup>108</sup> Curtis Peebles, *High Frontier: The U.S. Air Force and the Military Space Program* (Washington D.C.: Air Force History and Museums Program, 1997), 76-77.

<sup>109</sup> Briefing, Lee Brady, chief, PMA-242 Defense Suppression Systems, subject: Quick Bolt ACTD Status Brief, 24 October 2000.

performs the terminal acquisition and track of the target. Lastly the transmitter sends battle damage assessment via a weapon impact assessment message. All these things give the Quick Bolt a higher probability of kill than the HARM, while also providing battle damage assessment back through national collectors.<sup>110</sup>

In order to be more effective than the existing HARM, Quick Bolt needs to communicate with national assets. These national assets provide the information required to get a quick triangulation of the threats location while the Quick Bolt is still on the aircraft rail. Once the Quick Bolt has identified and geo-located the threat through sensor fusion of the on and off-board data, indications of the threat type, location are provided to the pilot's display. If the threat is deemed a high enough priority, the pilot selects the threat and employs the weapon. After launch the Quick Bolt sends data back through national assets that allow personnel to determine exactly where the weapons impacted, precluding untrue claims of collateral damage.<sup>111</sup>

The resulting concept of Quick Bolt promises a capability against a threat that shuts down and/or employs advanced waveforms, while minimizing fratricide and increasing lethality against an expanded target set. However, there are some implications to developing a weapon that depends so highly on national assets.<sup>112</sup>

Developing the Quick Bolt as an effective weapon is not an easy task. There are several challenges to the concept proposed by the US Navy. First, as described above, the Quick Bolt relies heavily on off-board sources of ELINT. This introduces two problems with respect to ELINT availability. The first problem is the availability of time for national assets to spend dedicated to providing data to individual weapons. There are many demands on US national assets from the operational level to the strategic level. Making sure that the assets are available to communicate with the Quick Bolt whenever it is being employed will be crucial. Second, these National assets are not likely to be in geosynchronous orbit over the threat locations. This means that there needs to be a robust constellation of satellites to communicate with the Quick Bolt as they pass overhead.

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<sup>110</sup> Ibid.

<sup>111</sup> Ibid.

<sup>112</sup> Ibid.

This may result in occasional gaps in coverage, and thus loss of the Quick Bolt capability. Even if there were enough national assets available to provide continuous coverage, the Quick Bolt may have to constantly make contact with new satellites as they pass in and out of the theater. This continuous reacquisition with national assets increases the likelihood that communication might be lost at a critical point.

The second challenge has to do with the accuracy of the ELINT sent to the Quick Bolt from national assets. As mentioned in the Space-Based Weapons section, each ELINT cut from a detector has an associated error ellipse. The target location is assumed to be in the middle of the ellipse. If you subsequently get another source to detect the same threat from a different angle, the intersection of the error ellipses can be used to triangulate the threat location. However, the farther the detector is from the emitter, the larger the ellipse. Therefore, national assets have much larger error ellipses than the F-16CJ HTS, or even the RC-135 Rivet Joint. At first look this should not create a problem, but if the ellipse gets too large they can contain multiple threats. It becomes increasingly difficult to correlate threat tracks and fuse the data into a single threat geo-location. This is further amplified by threat ambiguities. Many of the radar threats present today are ambiguous, a situation bound to be worse in the future. To help resolve the ambiguities, planners develop a threat priority list based on the threats present in the theater and the lethality of the threat. These priorities will help the Quick Bolt resolve ambiguities in its internal processor. However, national assets are not theater specific. They will not be programmed with the same ambiguity logic as a Quick Bolt employed in China, for example. Therefore, what the national assets detect and identify and what the Quick Bolt thinks it sees may very well be two different things. This may prevent sensor fusion and therefore geo-location, even though all assets are actually seeing the same emitter.

Quick Bolt offers a solution to the problem facing HARM shooters of today, the relative ineffectiveness of the HARM employed against a smart radar operator. It takes the strength of the HARM, its homing capability, and combines it with the vast information collected from the sensors to provide a responsive and effective weapon. However, there are still significant challenges to making Quick Bolt a reality.

Other advanced weapons provide a similar capability to enhance the effectiveness of the SEAD aircraft. The Small Smart Bomb (SSB) does this through increasing the weapons payload of various aircraft without sacrificing capability. The SSB initiative is designed to provide a weapon with the penetration effects achieved through today's 2000 lb BLU-109, but in a much smaller package. This would allow three SSBs to be carried in the same space as one 2000 lb bomb. This effect is achieved by making the SSB very accurate. A weapon's destructiveness varies inversely with the cube of the miss distance, while it is directly proportional to the explosive weight.<sup>113</sup> Therefore, a very accurate bomb can have significantly reduced explosive power, and thus size. In fact the SSB only weighs 250 lbs. The SSB employs an INS/GPS guidance unit in conjunction with differential GPS (using all 12 channels versus only 5) corrections to achieve a 5-8m CEP. A Swing Wing Adapter Kit can be fit to the SSB to increase the standoff range to over 25nm when released from high altitude. A later version will further increase the penetration capability of the SSB through enhanced explosives and the use of liners to control the fragmentation.<sup>114</sup>

The Low Cost Autonomous Attack System (LOCAAS) is another advanced weapon that could greatly enhance the survivability of traditional manned aircraft. LOCAAS is a low-cost laser detection and ranging (LADAR) sensor coupled with a multimode warhead on a powered airframe (fig. 5). It is designed to autonomously search for, detect, identify, attack, and destroy a variety of targets including SAMs at a standoff range of 90nm. The powered LOCAAS uses a small turbojet engine to provide power for 30 minutes and propel the weapon over a 33nm search area.<sup>115</sup> It incorporates automatic target recognition (ATR) and automatic target acquisition (ATA) algorithms that allow LOCAAS to autonomously differentiate between targets, communicate with

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<sup>113</sup> David R. Mets, "Air Armament Technology for the Deep Attack: Did it Work? What if it Works Next Time," (Maxwell AFB, AL: School of Advanced Airpower Studies, March 4, 1999), n.p..

<sup>114</sup> "Small Smart Bomb, Miniature Munition Capability," *FAS Military Analysis Network*, 29 November 1999, n.p.; on-line, Internet, 15 March 2001, available from <http://www.fas.org/man/dod-101/sys/smart/mmc.htm>.

<sup>115</sup> "Low Cost Autonomous Attack System (LOCAAS), Miniature Munition Capability," *FAS Military Analysis Network*, 29 November 1999, n.p.; on-line, Internet, 15 March 2001, available from <http://www.fas.org/man/dod-101/sys/smart/locaas.htm>.

other LOCAASs, and then conduct its attacks.<sup>116</sup> Once an attack is initiated the multimode warhead will select the appropriate mode based on the target type as determined by the ATR software. The modes available are stretching rod for hard armor penetration, aerostable slug for increased standoff, or fragments for soft target kill.<sup>117</sup> Not everyone is comfortable with a pack of LOCAASs flying around like a swarm of killer bees. Instead, many still feel there should be a requirement for a man-in-the-loop to do target verification and attack consent. That would reduce the possibility of fratricide or collateral damage due to faulty ATR algorithms. In fact, the US Navy already has a missile designated SLAM-ER that takes advantage of the emerging ATR technology. However, this early version of ATR has not proven reliable enough yet to take the man out of the loop. To date the Navy still uses a human being for target recognition and designation.<sup>118</sup>



**Figure 5. Low Cost Autonomous Attack System (Air Force Research Laboratory, Eglin AFB).**

The ATR and ATA technologies are just two of the 70 programs related to LOCAAS that can be applied to other weapons. These technologies help increase the lethality of weapons while reducing the risk to aircrews. However, these advanced

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<sup>116</sup> Clifford Beal, "Brave New World," *Jane's Defense Weekly*, 9 February 2000, 25.

<sup>117</sup> "Low Cost Autonomous Attack System (LOCAAS), Miniature Munition Capability," *FAS Military Analysis Network*, 29 November 1999, n.p.; on-line, Internet, 15 March 2001, available from <http://www.fas.org/man/dod-101/sys/smart/locaas.htm>.

weapons alone don't increase the ability to do reactive SEAD. They must be launched to the appropriate location, with a specific target to look for, and with critical timing. There is little time for an autonomous weapon to cruise to a target area, search that area, locate and identify the target, and then attack it, if the target is shooting at friendly aircraft. These weapons must be well integrated with their launch platforms to know exactly what and where to look for the target. Only through this integrated approach can these advanced autonomous weapons contribute to the reactive SEAD mission.

One final advanced capability for the SEAD mission comes from the Miniature Air-Launched Decoy (MALD). Although not a weapon in itself, the MALD increases the effectiveness of other systems. It is a low cost, expendable air-launched decoy designed to enhance the survivability of friendly aircraft by diluting and confusing enemy air defense systems. Once launched the MALD will not require any off-board communication or guidance. MALD operations focus on stimulating enemy air defenses so that SEAD aircraft can target them.<sup>119</sup> This standoff ability allowed by employing MALD increases the survivability of SEAD aircraft while also increasing their effectiveness as was done with the drones and TALDs during the Gulf War. The MALD provides the necessary decoy without the significant logistics and support requirements of the RPVs used during the Gulf War. Additionally, the reduced size of the MALD increases the carriage capability over the Navy's TALD. All together these advanced capabilities provide increased survivability to manned aircraft.

### **Unmanned Combat Aerial Vehicle**

The UCAVs have historically been used to perform strike missions to reduce the risk to aircrews. However, with the increasingly lethal enemy air defenses, the SEAD role has become particularly dangerous. Additionally, the U.S. has limited resources to fulfill the SEAD mission. Therefore, the Air Force is considering the UCAV as a possible solution to the SEAD challenges. The Defense Advanced Research Projects Agency (DARPA), in conjunction with the Air Force, has set out to establish the

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<sup>118</sup> Ibid., 24.

technological feasibility and affordability of a UCAV. For a UCAV to be acceptable it must be at least as capable and more affordable than other manned aircraft options.<sup>120</sup> The object of the program is to design, develop, integrate, and demonstrate the critical Technologies, Processes, and System Attributes (TPSAs) pertaining to an operational UCAV. The four critical TPSAs are:<sup>121</sup>

- Compatibility with integrated battlespace
- Secure robust communications
- Adaptive autonomy
- Advanced cognitive aids

To meet these critical TPSAs, DARPA and the Air Force established a three phased Advanced Technology Demonstration (ATD) begun in October 1997, that may eventually result in a fully capable version of the UCAV. Should the Air Force decide to proceed further, this will ease the transition to operational production. The first phase began in fiscal year (FY) 1998 and provided four awards to companies for the purpose of developing competing designs. The company design with the greatest potential to meet the TPSAs was selected to proceed to the second phase.<sup>122</sup>

In March 1998, DARPA selected Boeing Phantom Works to proceed into the second phase. The second phase is 42 months long, during which time Boeing will design, develop, integrate, and demonstrate a UCAV that will mature and validate the critical and enabling TPSAs. This phase is currently proceeding through a series of 82 simulation, ground and flight tests, which will be complete by the end of FY 2002. As of April 2001, Boeing had completed fabrication of the first UCAV demonstration system, which consists of an X-45A air vehicle (fig. 6), a reconfigurable mission control station, and storage container. Boeing also had a second X-45A in assembly.<sup>123</sup>

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<sup>119</sup> "Miniature Air-Launched Decoy (MALD)," *FAS Military Analysis Network*, 9 January 1999, n.p.: on-line, Internet, 15 March 2001, available from <http://www.fas.org/man/dod-101/sys/ac/equip/mald.htm>.

<sup>120</sup> David R. Honeywell, Senior Systems Analyst, HQ USAF/XORR, "UAV &UCAV Update," Presentation, Checkmate 2001 Strategy Conference, Arlington, VA., 22 February 2001.

<sup>121</sup> Department of Defense. *Department of Defense Report on Unmanned Advanced Capability Combat Aircraft and Ground Combat Vehicles* (Washington, D.C.: Office of the Secretary of Defense, March 2001), 15-17.

<sup>122</sup> *Ibid.*, 18-19.

<sup>123</sup> *Ibid.*

The third phase brings all the technologies together in a demonstration of the capabilities desired of the operational UCAV. This will result in the design and development of the third air vehicle, designated the X-45B. Additionally, the two X-45As will be modified to X-45B standards. This way the three can demonstrate multi-ship cooperation and coordination, as well as participate in a joint exercise with manned aircraft. This phase is scheduled to run into FY 2007. By this time the emphasis of the program will have shifted from technical feasibility to operational utility. Well into the third phase the Air Force will complete an Analysis of Alternatives to determine the viability of proceeding to a production UCAV for the SEAD mission.<sup>124</sup>

## **Development Results**

To date several promising results have been realized. With the assumptions that all TPSAs were achievable, Phase I revealed a potential 75% reduction in operations and support costs when compared to traditional manned aircraft, and the potential to kill a target for less than \$180,000. Throughout the phase the UCAV performed well.<sup>125</sup> Though the results have not yet been validated, the Phase I results indicate both the feasibility and affordability necessary to proceed with Phase II.



**Figure 6. Artist's conception of the X-45 employing ordnance (DARPA).**

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<sup>124</sup> Ibid., 19-20.

<sup>125</sup> The actual results of the analysis are classified and available in an secret appendix to the Department of Defense Report on Unmanned Advanced Capability Combat Aircraft and Ground Combat Vehicles, March 2001.

## Characteristics

The UCAV operational system is comprised of three components, the UCAV, the Mission Control Segment (MCS), and the Supportability Segment. Table 1 lists the characteristics of these major components.<sup>126</sup> The UCAV demonstrator being designed by Boeing is about two-thirds the size of an F-16 (fig. 7). It can be stored for up to ten years in a specialized container that allows external maintenance, monitoring, and software upgrades. A single business jet class engine propels the UCAV at high subsonic speeds and medium to high altitudes for a 500-1000 mile combat radius. It carries a variety of smart weapons internally, which include 12 SSBs or 4 advanced anti-radiation missiles or a mixture of the two. It can also carry LOCAAS, MALD, JDAM 500/1000, or the range extension SSB (fig. 8). For the SEAD mission the UCAV will be equipped with an electronic support suite and a high resolution SAR for precision geolocation and identification of the threats. The UCAV can communicate by both line-of-sight and satellite to the mission control segment. From the mission control segment operators and planners can provide guidance and mission tasking to the UCAV.<sup>127</sup>

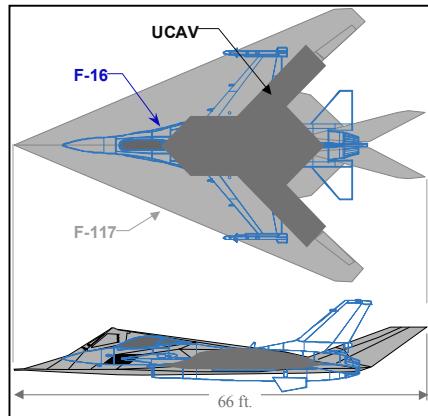
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<sup>126</sup> “Final Congressional Review 120800”, CD-ROM, DARPA, 2001.

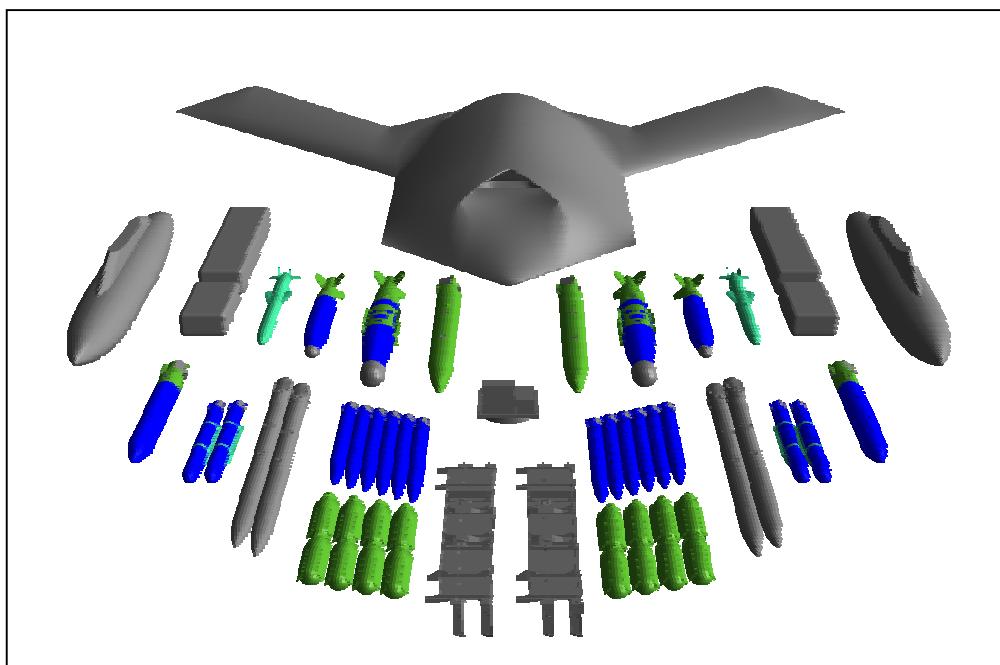
<sup>127</sup> Ibid.

**Table 1. Characteristics of the UCAV Major Components (DARPA)**

<p><b>Air Vehicle</b></p> <ul style="list-style-type: none"> <li>• Length: 27 ft</li> <li>• Wing Span: 34 ft</li> <li>• Height: 7 ft</li> <li>• Weight (dry): 8,000 lb</li> <li>• Propulsion: Single business jet class engine</li> <li>• Speed: High subsonic</li> <li>• Ceiling: Medium to high altitude</li> <li>• Range: 500 – 1,000 mile radius</li> <li>• Weapons bay: Internal</li> <li>• Payload: 1,000 – 3,000 lb</li> <li>• Weapons: Variety of smart weapons</li> <li>• Structure: Al substructure / composite skins</li> <li>• Subsystems: All electric</li> <li>• Comm: Satellite / Line-of-sight</li> </ul>	<p><b>Mission Control</b></p> <ul style="list-style-type: none"> <li>• Dynamic mission planning and replanning</li> <li>• Decision aids for planning and execution</li> <li>• Single operator manages multiple vehicles</li> <li>• Common operating picture on board and off board</li> <li>• Robust and secure communications</li> <li>• Dynamic distributed management of air vehicles (for combat as well as safe operations)</li> <li>• Task allocation by phase of mission</li> </ul>
<p><b>Supportability</b></p> <ul style="list-style-type: none"> <li>• Operator training using realistic simulations</li> <li>• Storage up to 10 years in containers - allowing external maintenance monitoring and software upgrades</li> <li>• Global deployment in 24 hours</li> <li>• Flexible transport or self-deployment <ul style="list-style-type: none"> <li>◦ (6 aircraft per C-17; 10 per C-5)</li> <li>◦ Reassembly (from containers) in less than 75-minutes</li> </ul> </li> <li>• Flexible basing locations</li> <li>• Operations/maintenance easily integrated with manned aircraft wing/squadron</li> </ul>	



**Figure 7. Comparison of UCAV size to F-16 and F-117 (DARPA).**

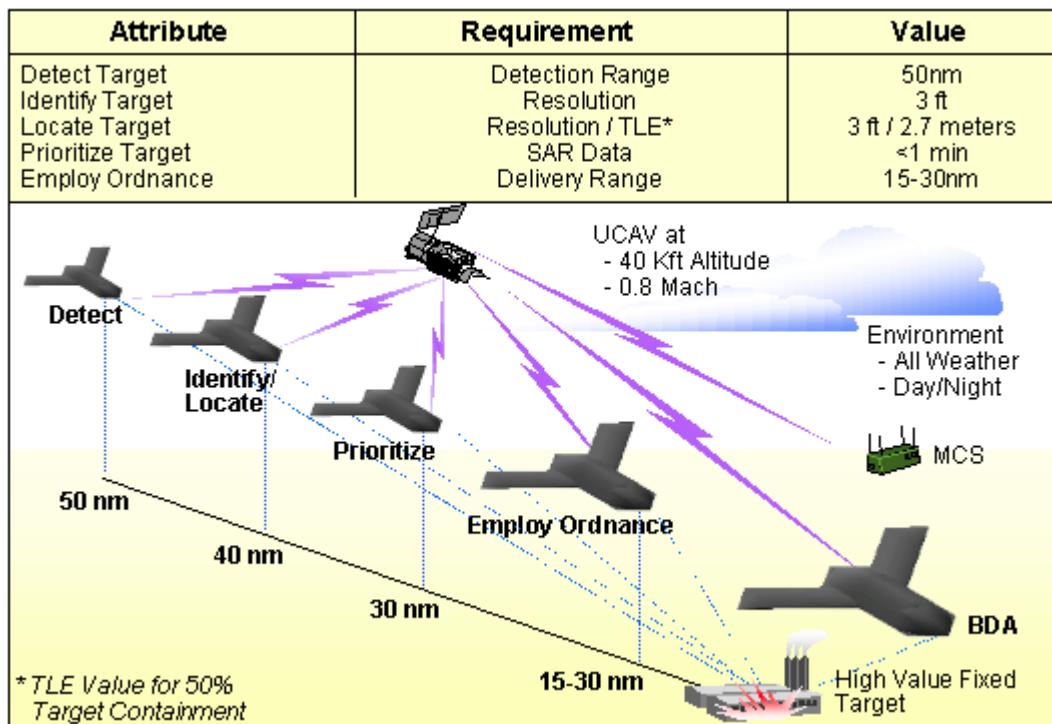


**Figure 8. Artist's conception of the X-45 with the array of potential weapons (DARPA).**

### **Concept of Operations**

There are two different variations of the SEAD mission: preemptive SEAD and reactive SEAD. In the preemptive role planners can preprogram the UCAV with the location of fixed sites. The UCAV will then autonomously taxi, takeoff, and proceed to the target area. It will then attempt to acquire the target through its various on and off-

board sensors. Depending on the final design criteria, the UCAV will either use automatic target recognition technology, and/or send the SAR patch back to the MCS through a MILSTAR satellite link for identification and verification. The operator will then give consent to employ ordnance on the target. The UCAV will then determine BDA and then either proceed to another target or return to base and land autonomously (fig. 9). Planners in the MCS may also task an airborne UCAV with this type of mission through the MILSTAR data link.<sup>128</sup>

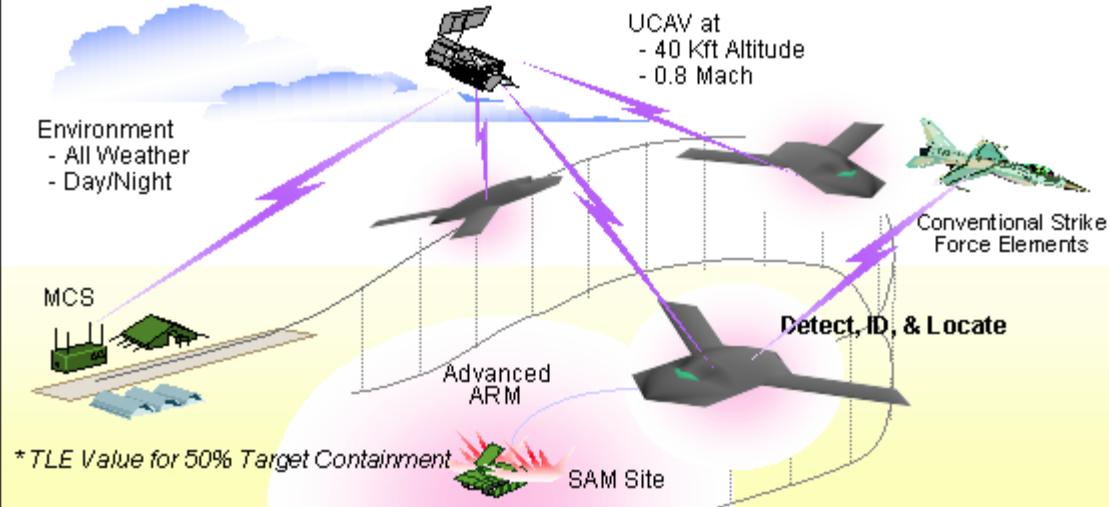


**Figure 9. Concept of operations for a UCAV against a preemptive target (DARPA).**

The reactive SEAD mission is more challenging than preemptive. In this role the UCAV responds to emitting air defenses. The air defenses may be responding to strike aircraft inbound to the threat area, or MALDs launched from the UCAV for the sole purpose of stimulating the air defenses. Whichever the reason, the UCAV needs to quickly detect, locate, and identify the threat while it is on-air, so ordnance can be expended. Figure 10 shows how a single UCAV would detect, locate, identify, prioritize,

<sup>128</sup> David R. Honeywell, Senior Systems Analyst, HQ USAF/XORR, interviewed by

and attack a mobile air defense threat. Optimally, however, a single UCAV would not be operating alone. One operator in the MCS can control up to four UCAVs. These UCAVs can communicate with one another, as well as to the MCS, which further enhances the UCAV's ability to quickly provide geolocations for detected threats (fig. 11).<sup>129</sup> This intraflight communication also allows UCAVs to share targeting information should one UCAV run out of ordnance.

Attribute	Requirement	Value
Detect Target	Detection Range	>80 nm
Identify Target	Signal Characterization	-----
Locate Target	Target Location Error*	50 m @ 50nm
Prioritize Target	On-Board Intelligent Aids	<10 sec
Employ Ordnance	Delivery Range	40-80 nm
 <p>UCAV at - 40 Kft Altitude - 0.8 Mach</p> <p>Environment - All Weather - Day/Night</p> <p>MCS</p> <p>Advanced ARM</p> <p>SAM Site</p> <p>Conventional Strike Force Elements</p> <p>*TLE Value for 50% Target Containment</p>		
<ul style="list-style-type: none"> <li>Supports Mission Objectives</li> <li>Directly supports vulnerable strike packages</li> <li>Timing/target requires specialized ordinance</li> <li>Permanent destruction is not required</li> <li>Timing is very critical</li> </ul>		

**Figure 10. A single UCAV executing reactive SEAD against a mobile threat (DARPA).**

As with the preemptive SEAD mission, depending on the technology incorporated in the final operational UCAV design, the amount of autonomy during an attack may vary. The

author, 19 April, 2001.

<sup>129</sup> "Final Congressional Review 120800", CD-ROM, DARPA, 2001.

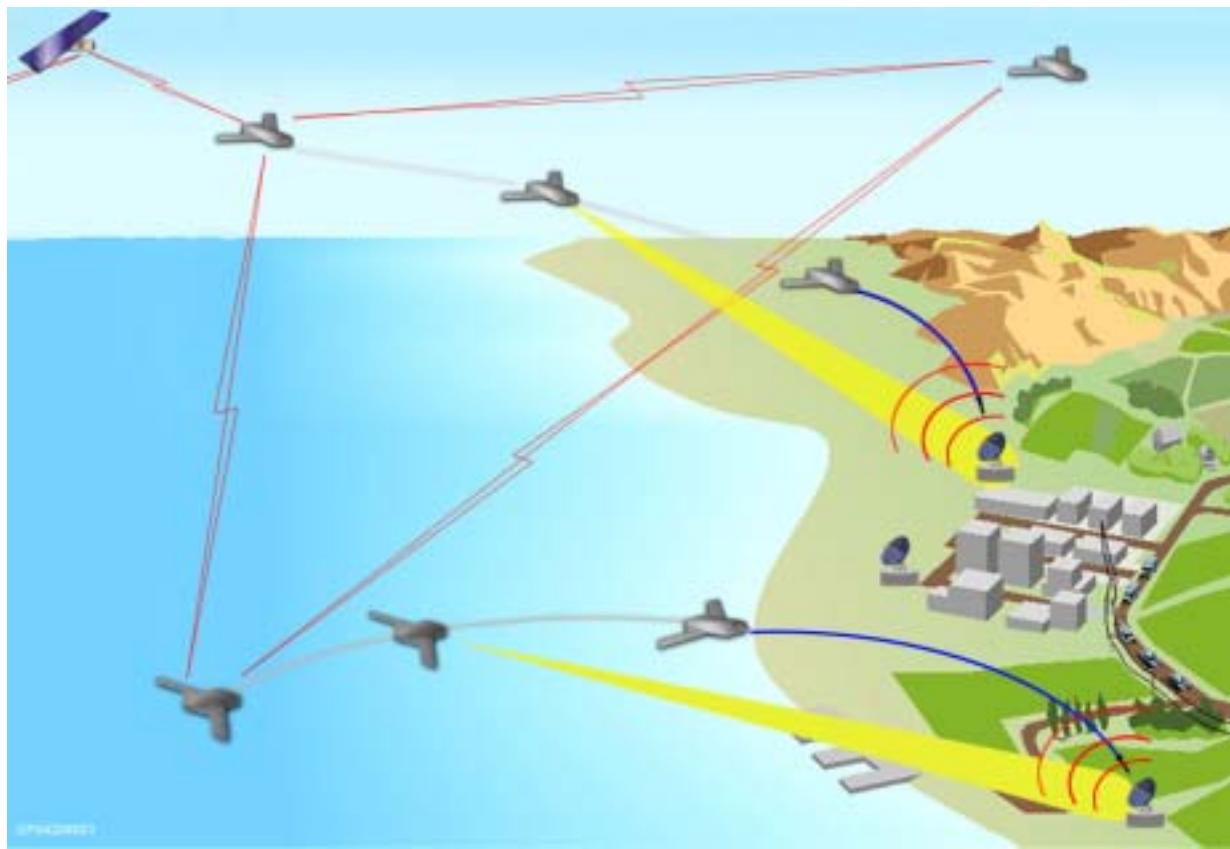
UCAV may have the ability to self-identify mobile threats through ATR, or it may need to data link a SAR patch to the MCS for identification and verification.<sup>130</sup>

## **Conclusion**

The 2015 environment for a major conventional conflict promises to be very deadly. In order for the U.S. to maintain its ability to establish air superiority over a potential enemy, the U.S. must invest in new SEAD technology. The USAF has identified three options it is considering for a FY 2005-2007 force structure decision: space-based SEAD capability, new modernized manned aircraft and weapons, and a UCAV. Each has its strengths and its weaknesses. The challenge is to determine which of the options provides is best suited to assume the SEAD mission.

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<sup>130</sup> David R. Honeywell, Senior Systems Analyst, HQ USAF/XORR, interviewed by author, 19 April, 2001.



**Figure 11. Three UCAVs working together to quickly locate and target emitting threats (DAPRA).**

## Chapter 6

# ANALYSIS

### Introduction

Why develop a UCAV for the SEAD mission? Chapter two lists the conditions when the U.S. typically considers the use of an unmanned vehicle. They are when the mission is high risk to human life, when human resources need to be diverted to other sources, or when overall efficiency and effectiveness is better through the use of automated systems.<sup>131</sup> This chapter analyzes the three SEAD options, to determine if UCAV meets these conditions.

### Analysis

The following section compares the three SEAD solutions based on the following criteria: fiscal cost, risk to human life, feasibility, and effectiveness. When evaluating the manned aircraft option, the author assumes a Joint Strike Fighter (JSF) as it is the only viable advanced manned strike aircraft being developed. If the JSF were to be cancelled, the USAF would have to make further buys of legacy aircraft. By comparison, the UCAV would likely outperform legacy aircraft in every category.

#### Space-Based Weapons

Of the three SEAD options space-based weapons are by far the most expensive. Development costs of these weapons are high, since most of these technologies need

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<sup>131</sup> Steven M. Shaker and Alan R. Wise, *War Without Men* (New York: Pergamon-Brassey's, 1988), 161.

significant advancement before being viable weapons. These weapons are likely to cost in the billions of dollars.<sup>132</sup> Additionally, there is huge cost in lifting these weapons into orbit. For example, the cost of using Titan IV boosters to lift satellites into orbit is \$285 million per launch.<sup>133</sup> However, these space-based weapons are much larger than current US boosters can lift. For example, the Titan IV can lift around 10,000 lbs, and the space-based laser is proposed to weigh around 70,000 lbs. Therefore, the U.S. will have to invest in a new booster that will probably cost over \$500 million per launch.<sup>134</sup> The operations costs of these weapons are relatively low once they are in orbit. However, because they are in orbit, the support costs are enormous for weapons requiring maintenance or replenishment.

Space-based weapons promise to be the lowest risk to human life. Since no personnel have to forward deploy in order to operate them, the risk to human life is low. The only personnel at increased risk would be those forward deployed to an Air Operations Center to coordinate their employment.

Space-based weapons are the least feasible of the three options for the 2015 time frame. Many of the proposed capabilities require significant investment of capital and time, an investment that still may not produce a weapon the U.S. can realistically lift into orbit. Without an Apollo like development effort, none of the potential space-based weapons can become operational before 2025<sup>135</sup>, well beyond the 2015 requirement. In fact, some may prove too complicated or expensive to implement.

Space-based weapons have the potential to be an effective SEAD weapon, if the U.S. can overcome the technical problems associated with accurately projecting that

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<sup>132</sup> A. Brent Marley, ACS Defense, Inc, interviewed by author, 7 May 2001.

<sup>133</sup> "Milstar 3 / Advanced Extremely High Frequency (AEHF)," *FAS Space Policy Project*, 25 April 2000, n.p.; on-line, Internet, 15 March 2000, available from <http://www.fas.org/spp/military/program/com/milstar3.htm>.

<sup>134</sup> A. Brent Marley, ACS Defense, Inc, interviewed by author, 7 May 2001.

<sup>135</sup> *Technology Seminar Game 2000, Concept Assessment*, Air Force Wargaming Institute, Maxwell AFB, AL.

much power from space. Once tasked, directed energy weapons can respond almost instantaneously, thus providing the reactive SEAD capability needed to defend a manned strike package. However, these weapons have limited effectiveness through clouds. Additionally, the U.S. would have to put enough weapons in orbit to provide near continuous coverage. Any gaps in coverage would be critical to planning any airborne operation. Some would argue that if the U.S. had this space-based weapons capability there would be no need for SEAD, since the U.S. would not need manned strike aircraft. However, most of the space-based weapons have limited usage before an expensive replenishment is required. Additionally, international treaty considerations would likely affect their ability to completely replace manned aircraft. Therefore, it is likely that the U.S. would limit their use to small-scale punitive strikes and strikes involving high-risk to airborne assets.

### **Modernized Manned Aircraft with Advanced Weapons**

The modernized manned aircraft option is significantly cheaper than space-based weapons. This option builds on well-established and understood design and manufacturing practices. It is also the option requiring the least number of changes to the current command and control network. The projected cost of a Joint Strike Fighter (JSF) is approximately equivalent to an F-16CJ today, around \$38 million.. Additionally, the USAF will not incur any additional cost for advanced weapons specifically for the JSF. The JSF is designed to carry and employ the existing 2000 lb series of weapons, as well as the new weapons like LOCAAS and SSB. However, the U.S. isn't developing LOCAAS and SSB just for JSF. The U.S. is looking to use these weapons to increase the survivability of other aircraft as well, including the UCAV. JSF will be able to leverage off these developments.

A big savings over legacy aircraft occurs in JSF's operations and support (O&S) costs. The savings in O&S costs is realized by making the JSF more reliable and maintainable. The major difference in the JSF over legacy aircraft is that there is no scheduled maintenance. Legacy aircraft have preventative maintenance accomplished based on hours of use or cycles. For example, F-16 maintainers must remove the jet fuel starter and send in to depot for overhaul after a specific number of engine starts.

Sometimes the jet fuel starter is in serious need of maintenance when it is removed. However, other times it appears brand new. The point is that parts are replaced or overhauled due to established time or cycle criteria. The JSF employs on-condition maintenance. The aircraft contains a network of internal sensors that can analyze the condition of the various parts and diagnose problems. Therefore, maintainers do maintenance on the JSF only when it is required. Additionally, human interaction is minimized, as the aircraft will communicate directly to the maintenance infrastructure. On-condition maintenance promises to reduce maintenance personnel necessary and the amount of maintenance accomplished, which are two huge costs. These initiatives will reduce JSF O&S costs by 30% of legacy aircraft.<sup>136</sup> However, this 30% savings assumes the same demands for training as legacy systems.

A large piece of the O&S costs of legacy aircraft is due to training sorties for pilot proficient. However, JSF training may well see a reduction in these training sorties for two reasons. First, range airspace in which to train is becoming increasingly difficult to preserve. As people move increasingly into the remote areas of the U.S. and other places around the world, the intrusion of noisy aircraft for training is becoming less and less tolerable. Additionally, as advanced weapons provide greater standoff from targets, aircrew training requires even larger areas of airspace. For example, the Nellis range complex north of Las Vegas, Nevada can typically support three to four different flights of aircraft each performing a separate training mission. However, as the 422 TES prepares to start operational testing of the F-22 at Nellis, they need the entire range complex to themselves, due to F-22's sizable employment ranges.<sup>137</sup> These requirements quickly deny some units training on an already congested range complex. Second, U.S. aircraft are becoming increasingly integrated with each other and other off-board sensors. This integration is critical to mission training. This leads to the costly requirement to routinely bring these assets together in large airspace to train. Consequently, the shortage of quality airspace may drive more training into high fidelity simulators. For these

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<sup>136</sup> "Boeing Demonstrates Ways to Reduce Joint Strike Fighter Maintenance, Life-Cycle Costs," *Boeing*, 28 June 2000, n.p.; on-line, Internet, 8 May 2001, available from [http://www.boeing.com/news/releases/2000/news\\_release\\_000628n.htm](http://www.boeing.com/news/releases/2000/news_release_000628n.htm).

<sup>137</sup> Major Brenton, Chief of Scheduling, 57<sup>th</sup> Wing, interviewed by author, 21 February 2001.

reasons the USAF is implementing simulator-based training called Distributed Mission Training (DMT).<sup>138</sup> The concept involves simulators from several different bases networked together to allow the execution of complex missions in a virtual battlespace. The use of these training devices will significantly reduce the O&S costs well beyond the 30% savings already forecast.

Of the three SEAD options manned aircraft have the highest risk to human life. This is due to the proximity of aircrew to the enemy air defenses. As compared to legacy aircraft, the JSF's sensor suite combined with low observable technology and advanced weapons will provide significantly improved survivability, even against advanced surface-to-air missiles. However operating within the vicinity of these threats does increase the risk to human life as compared to the other two SEAD options. Furthermore, if a potential US adversary makes unexpected advances in anti-stealth technology, the increased risk to human life may make UCAV even more desirable. This would be especially true during the first few days of a major conflict, when an enemy IADS will still be intact.

Manned aircraft are a proven application of airpower. Even with the significant technological advances being incorporated into the JSF, manned aircraft are still the most feasible of the three SEAD options. In fact, at the time of this research, most of the technologies required to field JSF had already been demonstrated. The largest challenge remaining was the sensor fusion required to handle all data generated by on-board and off-board sensors. Since, most of the technological challenges have already been addressed, the Air Force could move up initial JSF production to as early as 2008 if necessary.<sup>139</sup>

Manned aircraft have proven their ability to effectively execute the SEAD mission. The USAF has vast experience developing manned SEAD aircraft. Additionally, the doctrine, ROE, and tactical expertise exist for manned SEAD. This experience will carry over and be applicable to JSF. There is little doubt the JSF could effectively execute the SEAD mission of 2015.

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<sup>138</sup> Ibid.

## Unmanned Combat Aerial Vehicle

DARPA reports the UCAV will be the cheapest of the three SEAD options to produce, operate and maintain. Because of the vehicles size, two-thirds that of an F-16, and since it doesn't have to support or integrate with a human being, the DARPA claims each UCAV will cost about one-third of a JSF. They also report that the O&S costs for the UCAV will be 50-80% less than an F-16CJ HTS. This is due largely to the concept of operations during peacetime. DARPA envisions the UCAVs placed in their storage containers and packed away for up to ten years, or until they are needed. These containers allow the limited maintenance and testing required without removing them from storage. Additionally, like the JSF, the UCAV will incorporate on-condition maintenance. Furthermore, the UCAV does not require day-to-day flight for pilot proficiency, as with a manned aircraft. Since the operators are well removed the actual flying operations, much of their training can be accomplished in simulators. Additionally, the ratio of operators to air vehicles is not one to one, as in piloted aircraft; there will be one operator controlling up to four UCAVs from the Mission Control Segment (MCS).<sup>140</sup> For these reasons there is a reduction in O&S costs due to reduced spare parts, maintenance personnel and operations personnel.

However, these O&S savings assume that only eight UCAVs are out of storage at a time for training, testing, and exercises.<sup>141</sup> This number may be a bit optimistic. Even though UCAV operators can get their training in a simulator, manned aircraft will need to integrate with these UCAVs. They will need to participate in live exercises. Additionally, they are likely to enter into the high operations tempo common to US SEAD assets today. Therefore, more than eight UCAVs will be out of storage at one time, resulting in higher than projected O&S costs.

Like space-based weapons, the UCAV offers a SEAD solution with very low risk to human life. The greatest risk reduction is obviously the removal of the aircrew from the vehicle. However, operators will still be forward deployed to man the MCS. If the

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<sup>139</sup> Lt Col Christopher Weggeman, Chief JSF Operations Branch, ACC/DR-JSF, "Road Show Brief," Presentation. School of Advanced Airpower Studies, Maxwell AFB, AL., 1 May 2001.

<sup>140</sup> "Final Congressional Review 120800", CD-ROM, DARPA, 2001.

<sup>141</sup> *Ibid.*

UCAV ends up as effective and survivable as DAPRA projects, the U.S. can expect that the MCS will become a very desirable target for an enemy. Consequently, the UCAV is not as low risk to human life as a space-based option.

The UCAV, like the manned aircraft, is much more feasible than the space-based option. Much of the technology has either been leveraged from the UAVs like Global Hawk, and from F-22 and JSF development. Therefore, much of the technology will be ready to meet a 2015 IOC. However, DARPA still faces some technological challenges. The first challenge is in the artificial intelligence (AI) needed for the UCAV to operate nearly autonomously. This builds on the Global Hawk UAV concept. However, the AI needed to fly and employ in a dynamic SEAD environment is much more complicated. The second challenge is sensor fusion of the on and off-board sensors. This sensor fusion is critical for effective AI decision-making.<sup>142</sup> Additionally, the UCAV's small size makes it dependant on advanced miniaturized weapons, which have yet to be completely developed. This need for an AI capability and its reliance on weapons not yet developed is what makes the UCAV less feasible than manned aircraft.

Of the three SEAD options, my analysis suggests that the UCAV will be the most effective. However, this depends on the technology developments described above. If the UCAV is capable of reacting to the dynamic SEAD environment, its low observable properties allow it to be more survivable than even a JSF. This increased survivability translates to being able to operate closer to the threat, which in turn increases effectiveness against a highly mobile and lethal air defense threat.

## Summary

In summary, the UCAV is likely the cheapest of the three options, and runs a close second behind space-based weapons in risk to human life. However, manned aircraft lead UCAVs in feasibility. In the last category, mission effectiveness, the UCAV and JSF seem nearly tied. If the promised technology emerges, the UCAV will be slightly more effective. Table 2 rank orders the criteria used to evaluate the three SEAD options from best to worst. Figure 12 depicts a comparison of the ratings given to each of the

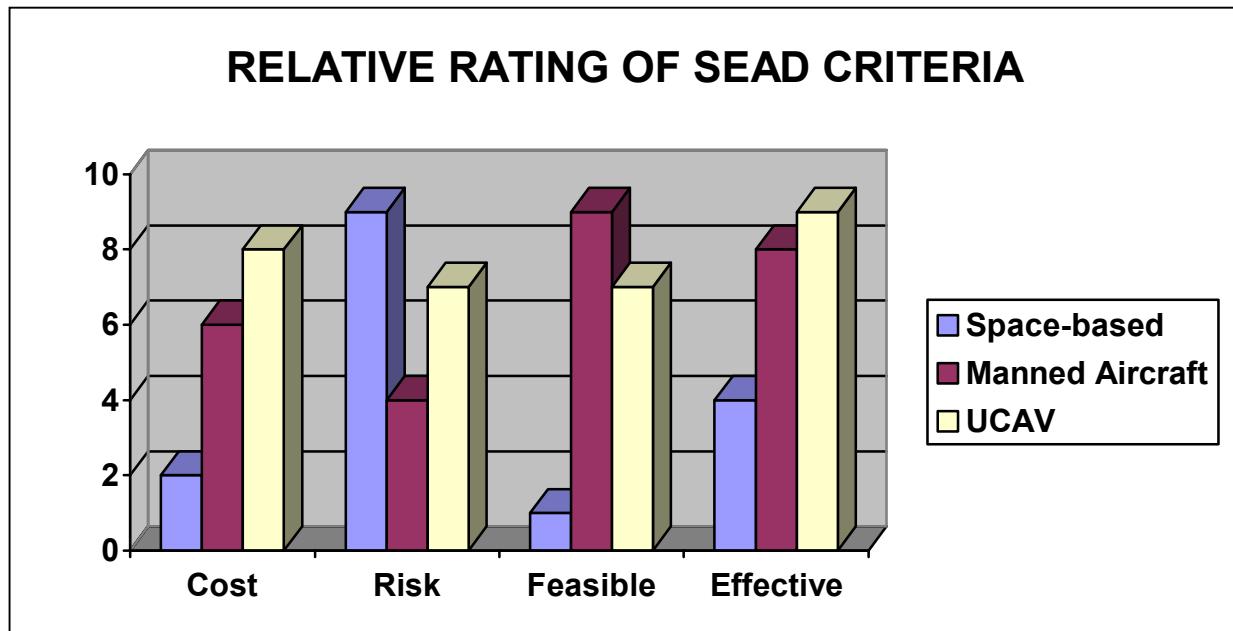
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<sup>142</sup> David R. Honeywell, Senior Systems Analyst, HQ USAF/XORR, interviewed by author, 19 April, 2001.

SEAD options, weighted according to the author's analysis. The scale used ranges from zero to ten, with ten being ideal. Evident in Figure 12, although the UCAV is a more effective SEAD weapons system, selection of the UCAV is not a cut and dry decision. Additionally, there are other issues affecting the UCAVs selection that are discussed in the next chapter.

**Table 2. Ratings of the three SEAD options from best to worst according to selected criteria**

Life Cycle Cost	Risk to Human Life	Feasibility	Mission Effectiveness
UCAV	Space-based Weapon	Manned Aircraft	UCAV
Manned Aircraft	UCAV	UCAV	Manned Aircraft
Space-based Weapon	Manned Aircraft	Space-based Weapon	Space-based Weapon



**Figure 12. Comparison of the three SEAD options weighted by author's analysis.**

## Chapter 7

# CONSIDERATIONS AND RECOMMENDATIONS

### Introduction

Besides the criteria used to determine if the UCAV can effectively execute the SEAD mission, there are other issues that affect whether the UCAV is the correct weapons system for the mission. The UCAV need to fit in with an overall USAF procurement strategy. Additionally, there are political and doctrinal issues that the USAF must consider. This chapter explores those issues, and presents final recommendations.

### Considerations

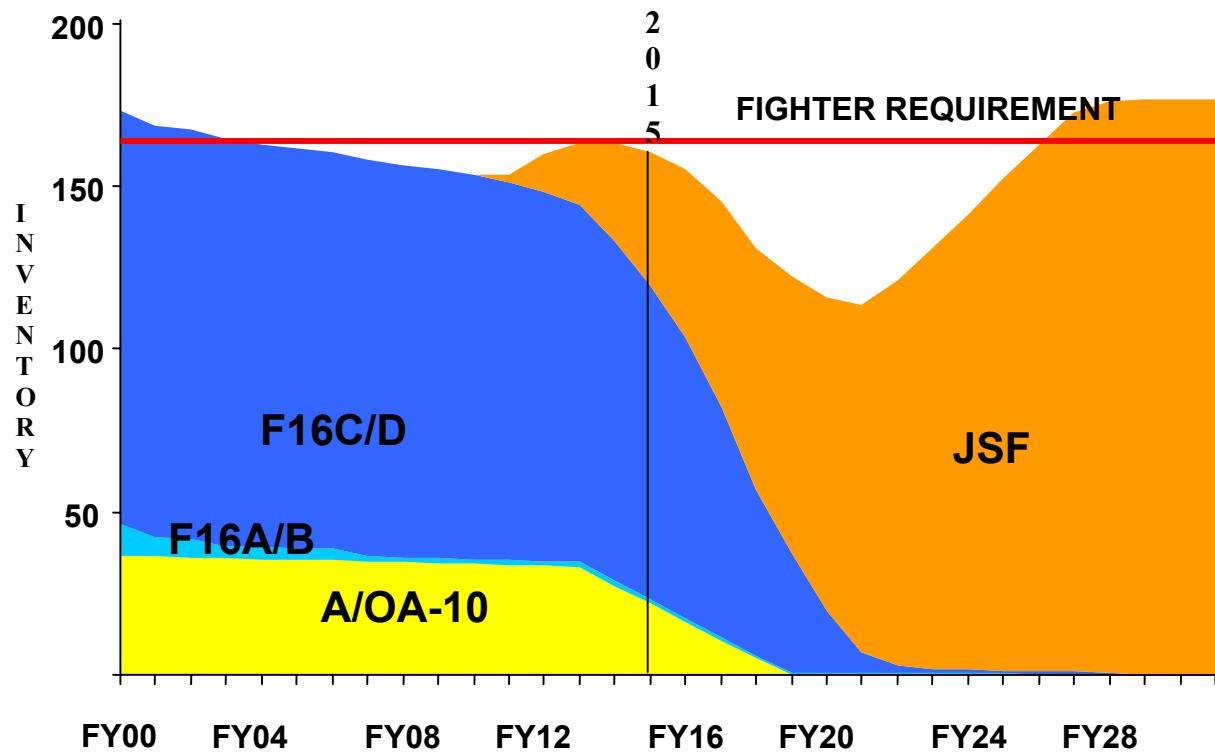
Besides the criteria used to compare the three SEAD options, there are some other issues the USAF needs to consider before implementing the UCAV in the SEAD role. First, the selection of a new SEAD weapon system for 2015 does not imply that the U.S. is only going to develop one of them. The USAF is not going to cancel the JSF based solely on selection of a UCAV for the SEAD mission. The current life expectancy of legacy fighter and attack aircraft is going to drive the acquisition of the JSF (fig.13).<sup>143</sup> Since the Air Force is planning on purchasing the JSF and it can effectively execute the SEAD mission, does the Air Force also need to invest in a UCAV? Since the UCAV promises to be slightly more effective, due primarily to its low observability, I recommend that the U.S. acquire both. However, since the UCAV and JSF are

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<sup>143</sup> Lt Col Christopher Weggeman, Chief JSF Operations Branch, ACC/DR-JSF, “Road Show Brief,” Presentation. School of Advanced Airpower Studies, Maxwell AFB, AL., 1 May 2001.

complementary in many ways, except air-to-air, a reduction in the buy of both systems may be warranted.

A second issue is the political considerations involved with employing a UCAV. During conflict, especially MOOTW, does the US deployment of an unmanned aircraft portray limited commitment and resolve on the part of the US leadership? Assuming there will still be manned aircraft involved, the incorporation of UCAVs should not have much effect. However, if the UCAV steps beyond the SEAD role to also doing strike missions, the U.S. may project a lack of resolve in some situations.



**Figure 13. Projection of F-16 and A-10 replacement with JSF.**

### Doctrinal Issues

There are some doctrinal issues that the USAF must consider before choosing to implement the UCAV option for the SEAD mission. Currently, Rules of Engagement (ROE) allow the right of self-defense for manned aircraft. Does this apply to unmanned aircraft? What if the UCAV is not shot at but just targeted by a SAM radar? For example, in Operations Desert Storm and Desert Shield, peacetime ROE allows US

service members to use force in self-defense in response to an attack or threat of attack on US or host nation forces, citizens, property or commercial assets.<sup>144</sup> A variation of this ROE in use in Operation Southern Watch and is what has allowed F-16CJ pilots to shoot back if “lit up” by and Iraqi air defense radars. If a piece of US equipment is threatened, is the U.S. willing to shoot at a manned site? During wartime I feel this is very cut and dried. It doesn’t matter whether the enemy is targeting the UCAV or just testing their radar. If the radar is a threat it should be engaged just as it is by manned aircraft today. The real issue is during military operations other than war. In scenarios like no-fly zone enforcement, peace enforcement, or force projection, the issue becomes more contentious. Each theater will need to spell out their ROE based on their specific situation. However, as a guideline, I believe the U.S. should have the right of self-defense for a UCAV if an adversary SAM targets it, regardless of whether a SAM is actually fired.

Another doctrinal issue involves the practicality of a UCAV during military operation other than war. Many of these operations that currently include SEAD aircraft, involve presenting a presence to an enemy that denies them the use of their sovereign airspace. Currently a flight of F-16CJs can do this mission without escort since they are multi-role. They can enforce a no-fly zone with their air-to-air ordnance and provide force protection against radar-aimed air defenses with their HARM Targeting System. However, the current UCAV concept does not carry or employ air-to-air ordnance. Therefore, other air superiority aircraft will have to do the air-to-air portion of the offensive counter air (OCA) mission. The UCAV will then also need to be present to provide force protection for these air-to-air aircraft. This leads to the next issue, integration with manned aircraft.

Currently, aircrews pre-plan airborne deconfliction to prevent mid-air collisions. However, things often don’t go as planned and aircrews communicate changes once airborne. Aircrews and UCAV operators can pre-plan their deconfliction plans as well. However, airborne changes are much more difficult to make, when dealing with a semi-autonomous UCAV. Additionally, when all else fails, pilots can fall back on see-and-

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<sup>144</sup> Command and General Staff College Student Text 27-1, *Military Law*, July 1999, 3-14.

avoid. When flying with a UCAV flight, the see-and-avoid is only on the side of the manned aircraft. The UCAV will only have Link 16 to provide situational awareness of other aircraft, but Link 16 may not display all aircraft. Many aircraft, particularly legacy aircraft, will only receive Link 16 information. They will not transmit back information back into Link 16. Therefore, any position reports of these aircraft will only come from surveillance aircraft, which may not indicate position accurately enough for deconfliction in a dynamic environment. For example, F-22 is not currently going to transmit to Link 16. This problem does not prevent integration of manned and unmanned aircraft. It just increases the risk of mid-air collision.

## Conclusions

Ever since the introduction of air power into the conduct of war, the U.S. has struggled to maintain a technological edge over its potential adversaries. This technological edge combined with superior training has allowed the U.S. to establish air superiority during all of its battles since Vietnam. However, this apparent superiority of air forces did not develop unchallenged. The enemy first tried to counter U.S. air power with air defenses that progressed from AAA and enemy fighters in Germany during WWII to advanced integrated air defense networks in Iraqi during the Gulf War. As the air defense threat lethality increased the U.S. made several attempts at unmanned aircraft to reduce the risk to aircrews. However, the technology to replace the manned aircraft was not feasible or effective. The U.S. also developed weapons to attack these air defensive systems directly, such as the Shrike and the HARM.

Today as the air defense threat continues to increase around the world, the technology has advanced such that the U.S. can develop a viable UCAV with the potential to execute the dynamic, reactive SEAD mission. However, is the UCAV the most effective choice for execution of the 2015 SEAD mission? Of the three options being considered, I evaluate the UCAV option as the most effective. This depends, though, on the ability of DARPA and Boeing to demonstrate the artificial intelligence, sensor fusion, and miniature weapons necessary to bring the UCAV up to the standards required for it to respond timely and accurately to advanced, mobile air defense threats. Looking beyond the technical issues DARPA and Boeing must solve, the US needs to

consider the doctrinal issues involved with a UCAV's right of self defense, UCAV integration with other manned aircraft, and the potential US image of lack of resolve. For these reasons, and the fact the U.S. is likely to purchase the JSF that can also effectively execute the SEAD mission, I don't believe the USAF should, or would want to transfer the reactive SEAD solely to the UCAV. Instead I think both systems should continue development, not in competition, but in a synergistic manner. The USAF needs to continue plans to field JSF, and then when time comes to do source selection for the UCAV, the Air Force should reevaluate the world threat environment. If the threat at that time does not exist to justify the UCAV as a SEAD platform, I believe the UCAV should go into limited production. A UCAV could perform the deep strike role, where the risk is too high for manned aircraft and many of the problems associated with the dynamic SEAD mission don't exist. Therefore, I believe the USAF should at least buy a limited number of the UCAVs for this role. However, if the added survivability of the UCAV is needed to compliment the JSF in the SEAD role, the UCAV should then enter full production. The USAF should employ the UCAV to take down the high-threat and mobile components of the enemy IADS for follow-on manned aircraft strikes. Additionally, it can strike deep into enemy territory, much like a cruise missile today, except the UCAV returns for reuse.

The technology is ripe for the employment of an autonomous UCAV. The air defense threat will decide whether the UCAV takes its place as the new Wild Weasel.

## *Glossary*

### **AAA – Anti-Aircraft Artillery**

AI – Artificial Intelligence  
AOC – Air Operations Center  
ATA – Automatic Target Acquisition  
ATD – Advanced Technology Demonstrator  
ATR – Automatic Target Recognition  
COMINT – Communications Intelligence  
DARPA – Defense Advanced Research Projects Agency  
DMT – Distributed Mission Training  
ECM – Electronic Counter Measures  
ELINT – Electronic Intelligence  
EOB – Electronic Order of Battle  
EW – Early Warning  
FY – Fiscal Year  
GPS – Global Positioning System

### **HVAA – High Value Airborne Assets**

HARM – High Speed Anti-radiation Missile  
HTS – HARM Targeting System  
IADS – Integrated Air Defense System  
ICBM – Intercontinental Ballistic Missile  
IDM – Improved Data Modem  
ISR – Intelligence, Surveillance, and Reconnaissance  
JDAM – Joint Direct Attack Munition  
JSF – Joint Strike Fighter  
LGB – Laser Guided Bomb  
LOCAAS – Low Cost Autonomous Attack System  
MALD – Miniature Air-Launched Decoy  
MCS – Mission Control Segment  
MOOTW – Military Operations of than War  
O&S – Operations and Support  
OCA – Offensive Counter Air  
 $P_k$  – Probability of Kill  
ROE – Rules of Engagement  
RPV – Remotely Piloted Vehicle  
SAM – Surface-to-Air Missile  
SAR – Synthetic Aperture Radar

SEAD – Suppression of Enemy Air Defenses

SIGINT – Signals Intelligence

SSB – Small Smart Bomb

TALD – Tactical Air Launched Decoy

TPSA – Technologies, Processes, and System Attributes

UAV – Unmanned Aerial Vehicle

UCAV – Unmanned Combat Aerial Vehicle

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